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Picture Projection with MAZDA Lamps

By

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National Lamp Works of General Electric Co.
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TABLE I

THE FIELDS OF APPLICATION FOR LAMPS USED IN PROJECTION

Service		Type of Projector	MAZDA Lamp	Approximate Limits Picture Width (Feet)	Approximate Limits Distance (Feet)
Motion Picture Theater		Standard Theater Motion Picture	900-watt, 30-amp.	16	100
Educational	**School and Church Auditorium Large Lecture Room Large Lodge Hall**	Standard Theater Motion Picture	900-watt, 30-amp.	16	100
		Semi-Portable Motion Picture	900-watt, 30-amp. 1000-watt, 115-volt	12 8	80 60
		Stereopticon (Glass Slide)	1000-watt, 115-volt 500-watt, 115-volt	14 12	100 75
		Semi-Portable Motion Picture	900-watt, 30-amp. 1000-watt, 115-volt	12 8	80 60
		Portable M. P. (35 mm. Film)	500 watt, 115-volt	8	50
	School Lecture Room Class Room Sunday School Small Lodge Room	Portable M. P. (16-mm. Film)	200-watt, 115-volt 200-watt, 50-volt	4 4	20 25
		Stereopticon (Glass Slide)	1000-watt, 115-volt 500-watt, 115-volt	14 12	100 75
		Stereopticon (Film Slide)	200-watt, 115-volt 50-watt, 115-volt	5 3	25 10
		Projector for Opaque Objects	1000-watt, 115-volt 500-watt, 115-volt*	. . . .	30 15
Home		Portable M. P. (16-mm. Film)	200-watt, 115-volt 200-watt, 50-volt 100-watt, 115-volt	4 4 3	20 25 15
		Stereopticon (Film Slide)	200-watt, 115-volt 50-watt, 115-volt	6 3	25 10
		Combined Stereopticon and Opaque Projector	500-watt, 115-volt	12 . .	75 25
Business		Portable M. P. (35-mm. Film)	500-watt, 115-volt	8	50
		Portable M. P. (16-mm. Film)	200-watt, 115-volt 200-watt, 50-volt	4 4	20 25
		Advertising Stereopticon (Glass Slide)	1000-watt, 115-volt 500-watt, 115-volt	10 8	60** 40**
		Advertising Stereopticon (Film Slide)	200-watt, 115-volt 50-watt, 115-volt	6 3	25 10
		Advertising M. P. Projector (35-mm. Film)	900-watt, 30-amp. 1000-watt, 115-volt 500-watt, 115-volt	12 8 8	75† 60 50
Traveling Exhibitor		Semi-Portable	900-watt, 30-amp. 600-watt, 20-amp. 1000-watt, 115-volt	12 8 8	80 70 60

* 500-watt lamp sufficient when translucent screen is employed.

** These limits assume use in brightly lighted districts, where extraneous light falls on screen. In dark districts, or where no stray light falls on the screen, the limits are those for "Steropticon (Glass Slide.")

† Outdoor application.

The table on page 42 shows the correct lamps for use in the equipments of various manufacturers.

Picture Projection With MAZDA Lamps

The use of MAZDA lamps for the projection of motion pictures in theaters is attended by numerous advantages. They are simple and economical in operation; they dissipate a minimum amount of electrical energy and they produce neither fumes nor gases. They may be used to advantage in theaters of small and medium size and are practically universally employed in projection equipments used outside of the theater.

The projected picture is characterized by an agreeable softness; the harsh contrasts that have so often defeated on the screen the finer qualities of the producer's art, are minimized; the proper relative values are given to all parts of the picture. The light is evenly distributed over the screen and is of constant intensity. In color it includes the entire range of the visible spectrum and hence it is adapted to the projection of colored pictures.

The use of motion pictures in fields outside of the photoplay house is becoming widespread. So popular is this form of presentation that, together with slide projection, it has brought about a new technique in education, has become a valuable aid in selling, and is rapidly developing into a larger factor in home recreation.

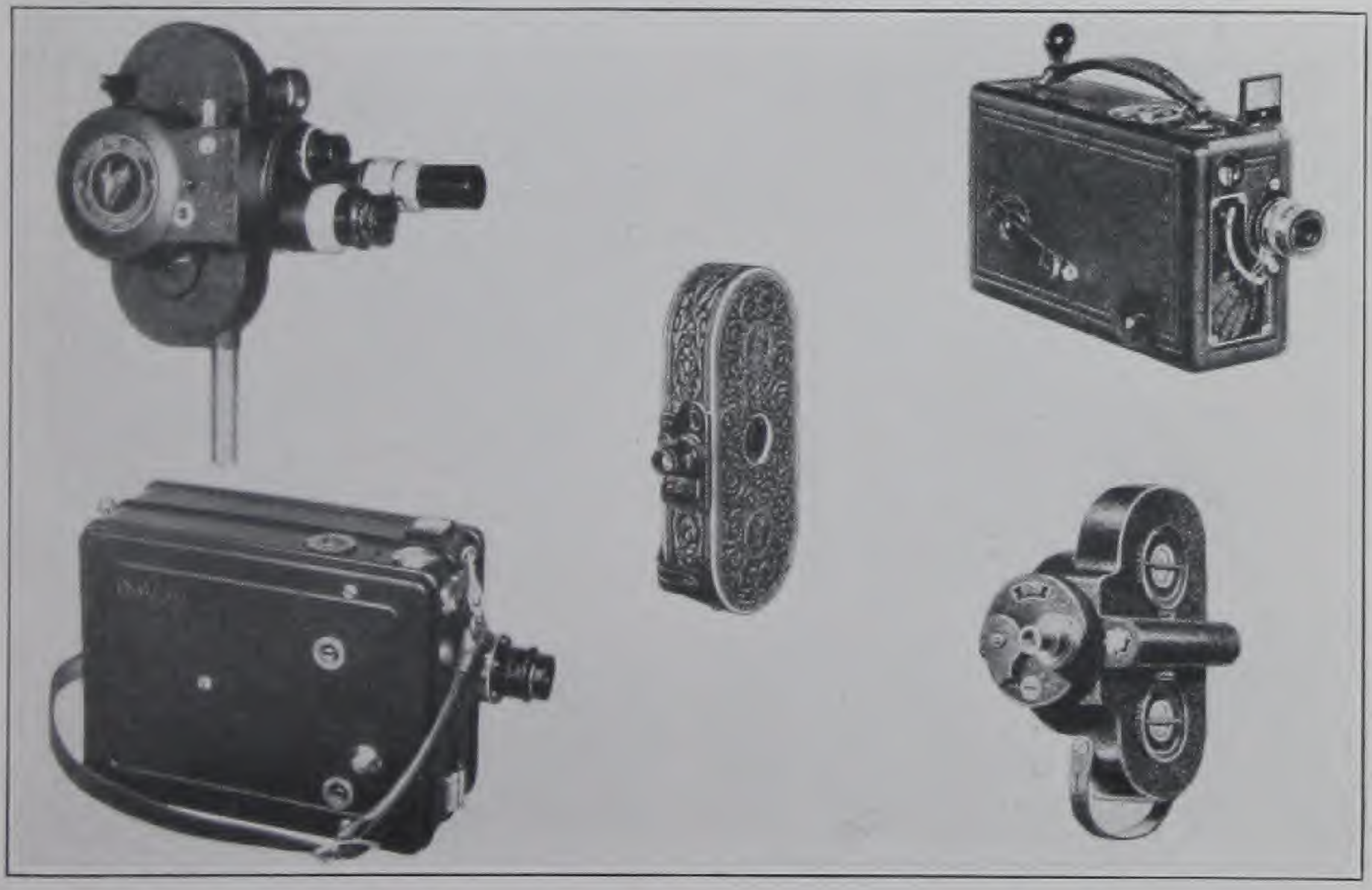
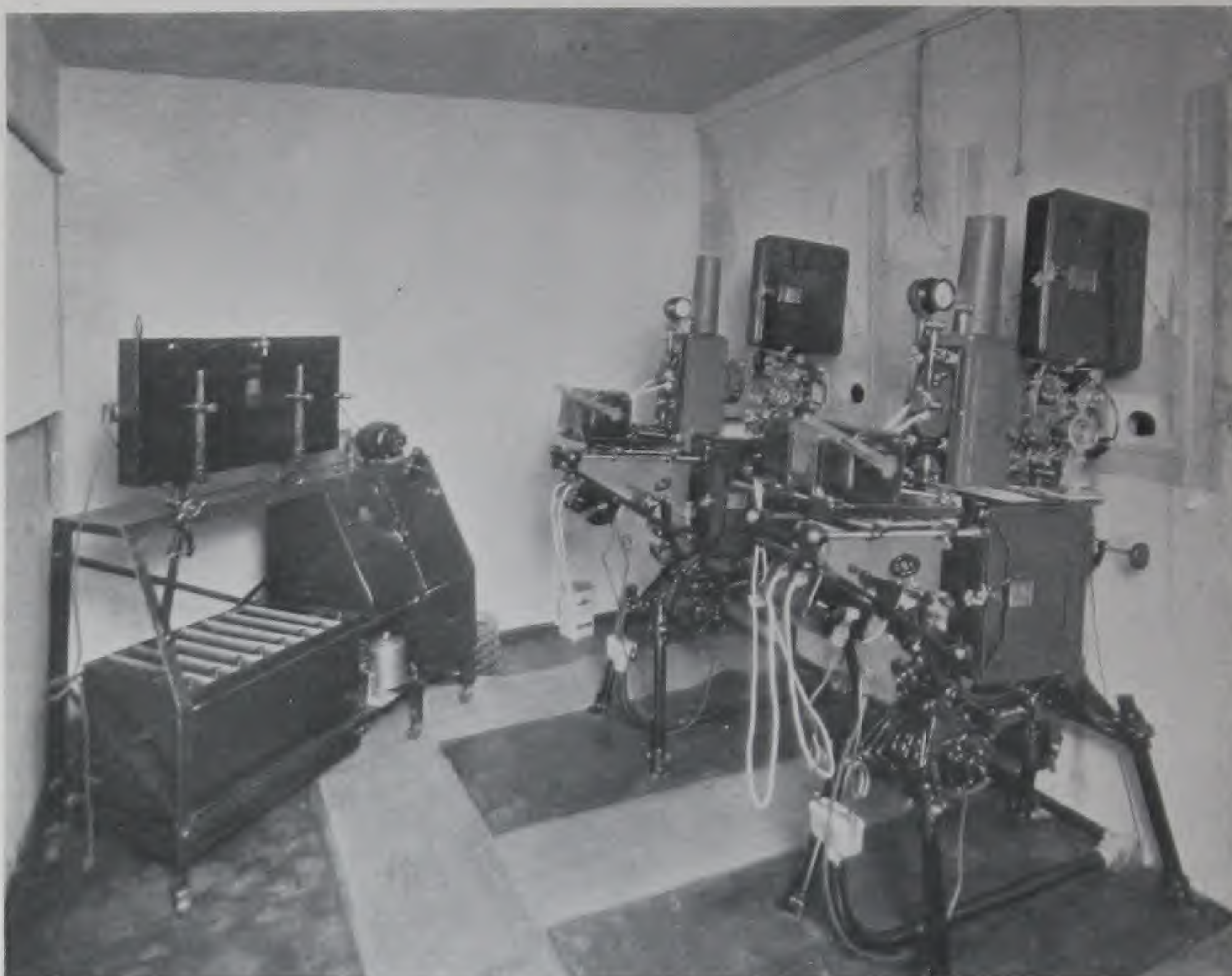
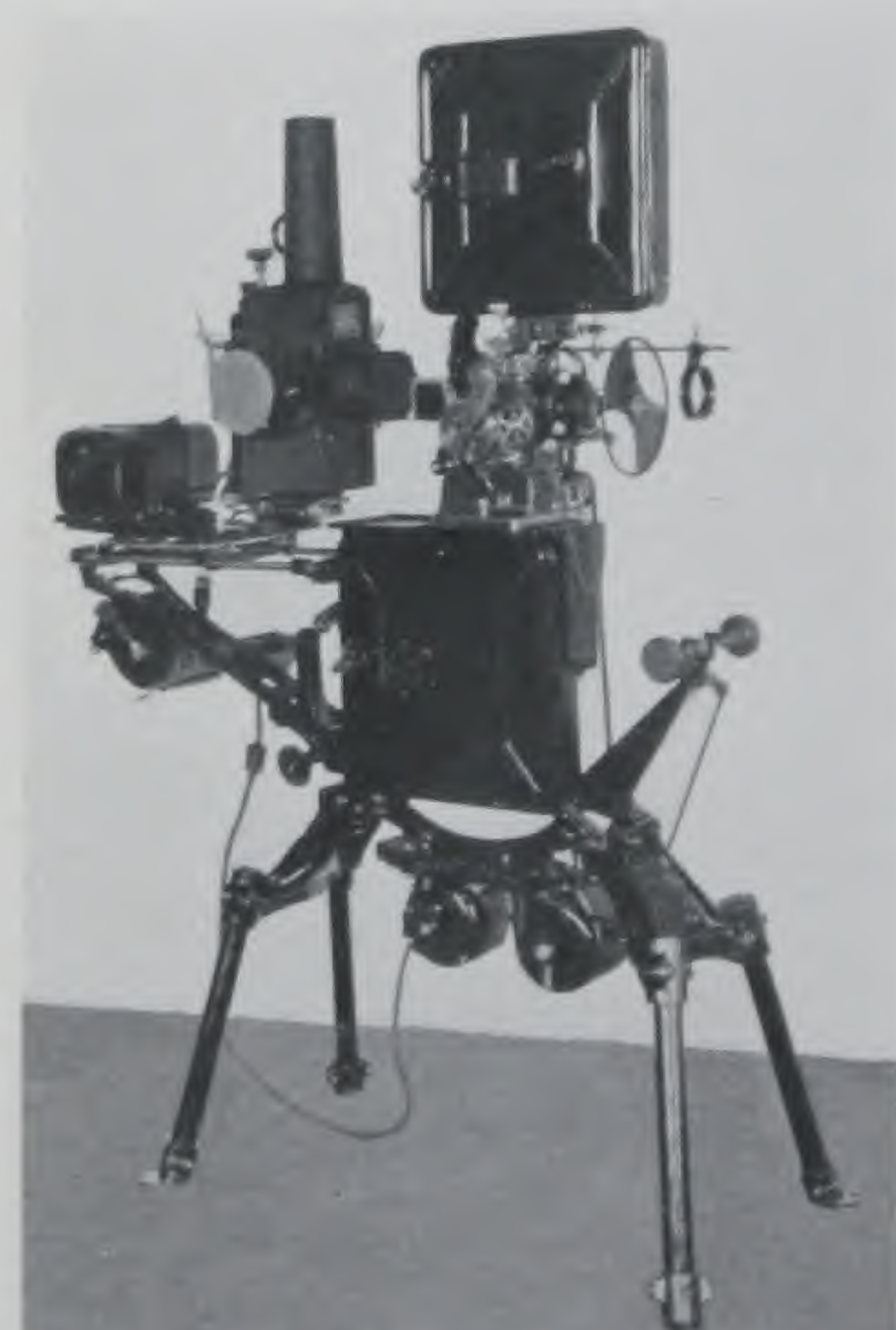


Fig. 1—The variety of small cameras now available have made amateur movies a fascinating hobby.





Some standard theater motion picture projectors fitted with incandescent equipment.

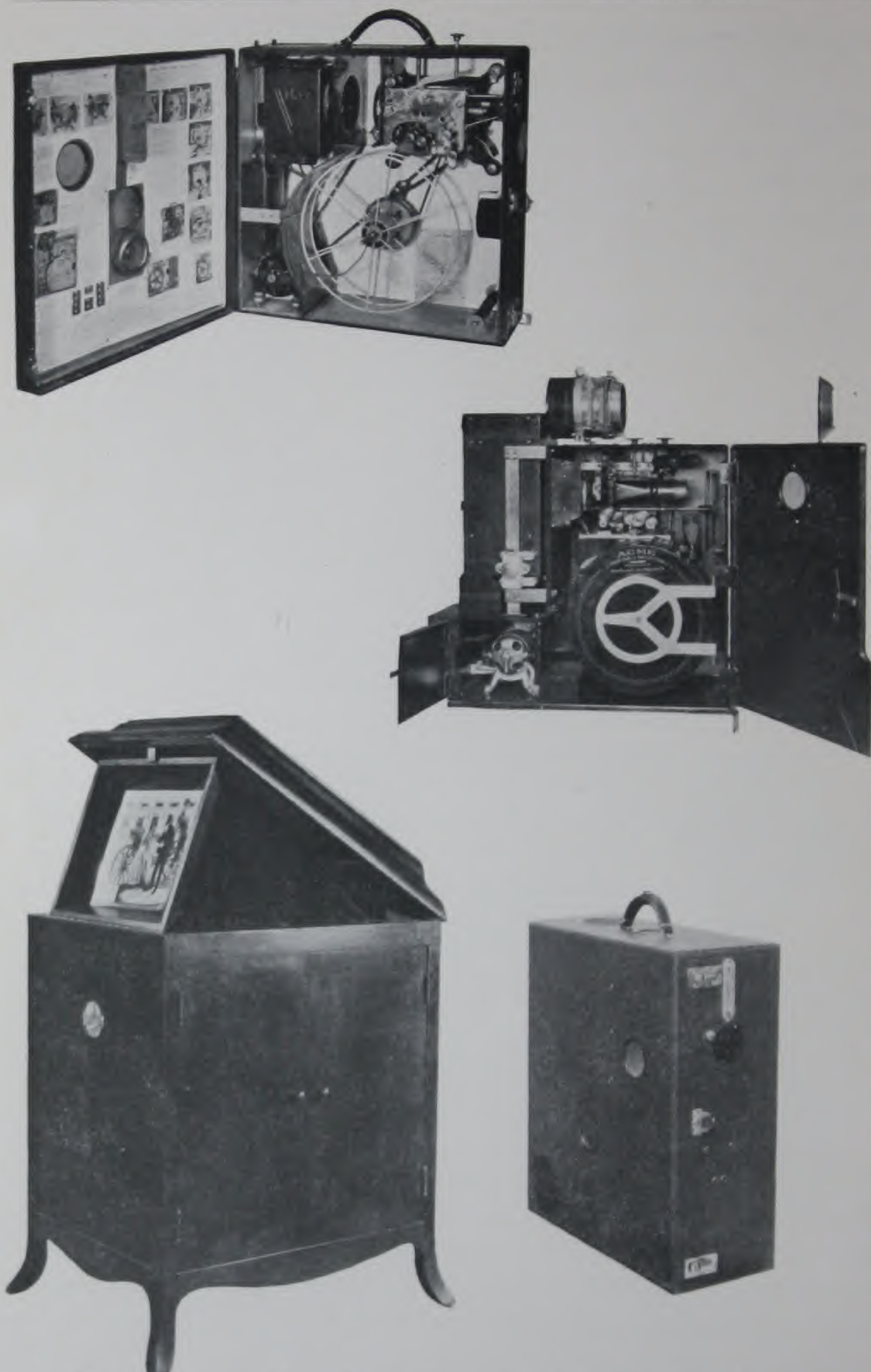
It will be noted from Table I that a variety of projection equipments find application in schools, churches, business, and the home, the particular type to be used depending upon the picture and auditorium size. Both the 35-mm. and 16-mm. standard film are employed in these fields. The former can be obtained in either the inflammable or non-inflammable stock, whereas the latter is obtainable only in the non-inflammable stock. All states require the use of fireproof booths in projection of inflammable film, but this requirement does not in most cases apply to the use of non-inflammable stock.

There is considerable economy in the use of 16-mm. film wherever it is applicable. Not only are there 2½ times the number of pictures to the foot, but also the exposed negative is converted into a positive print by a redevelopment process. The cost of finished pictures on 16-mm. film is at present $1.50 per 1,000 pictures, as compared with about $9.50 on the larger film. The weight of equipment using this small film is only one-fourth to one-third that of equipments using 35-mm. film.

Stereopticon projectors employing standard glass slides should be used in the auditorium and larger class room. There are available stereopticon projectors serving the same purpose as the lantern slide projectors but using lengths of 35-mm. film containing from 30 to 50 or more frames, each an individual picture. Either by the pressing of a lever or the turning of a knob, a single picture is brought into position before the aperture and held there as long as desired. These so-called film-slide projectors have much to recommend them from the standpoint of compactness, light weight, and freedom from slide breakage. It must be realized that it is not possible to project as large a picture with the same screen illumination as with standard lantern slides because of the smaller film aperture. The cost of film slides is approximately one-tenth that of glass slides.

Non-inflammable, 35-mm. film is used exclusively in these equipments. Some form of heat absorbing or reflecting screen must be placed between the condenser and the film if maximum illumination is desired; otherwise the film would warp or buckle. Manufacturers have therefore provided their equipments with heat filters which permit the picture to be viewed almost indefinitely.

The opaque projector, used only in the non-theatrical field, is a modified stereopticon that permits the projection of opaque objects or



Typical semi-portable and portable motion picture projectors using 35 mm. film.

pictures by reflected instead of transmitted light. Two lamps are employed for best results, one at either side of the copy, each fitted with

Fig. 2—Standard width (35 mm.) film compared with 16 mm. film; each roll contains 8,000 pictures (6-8 minutes projection).

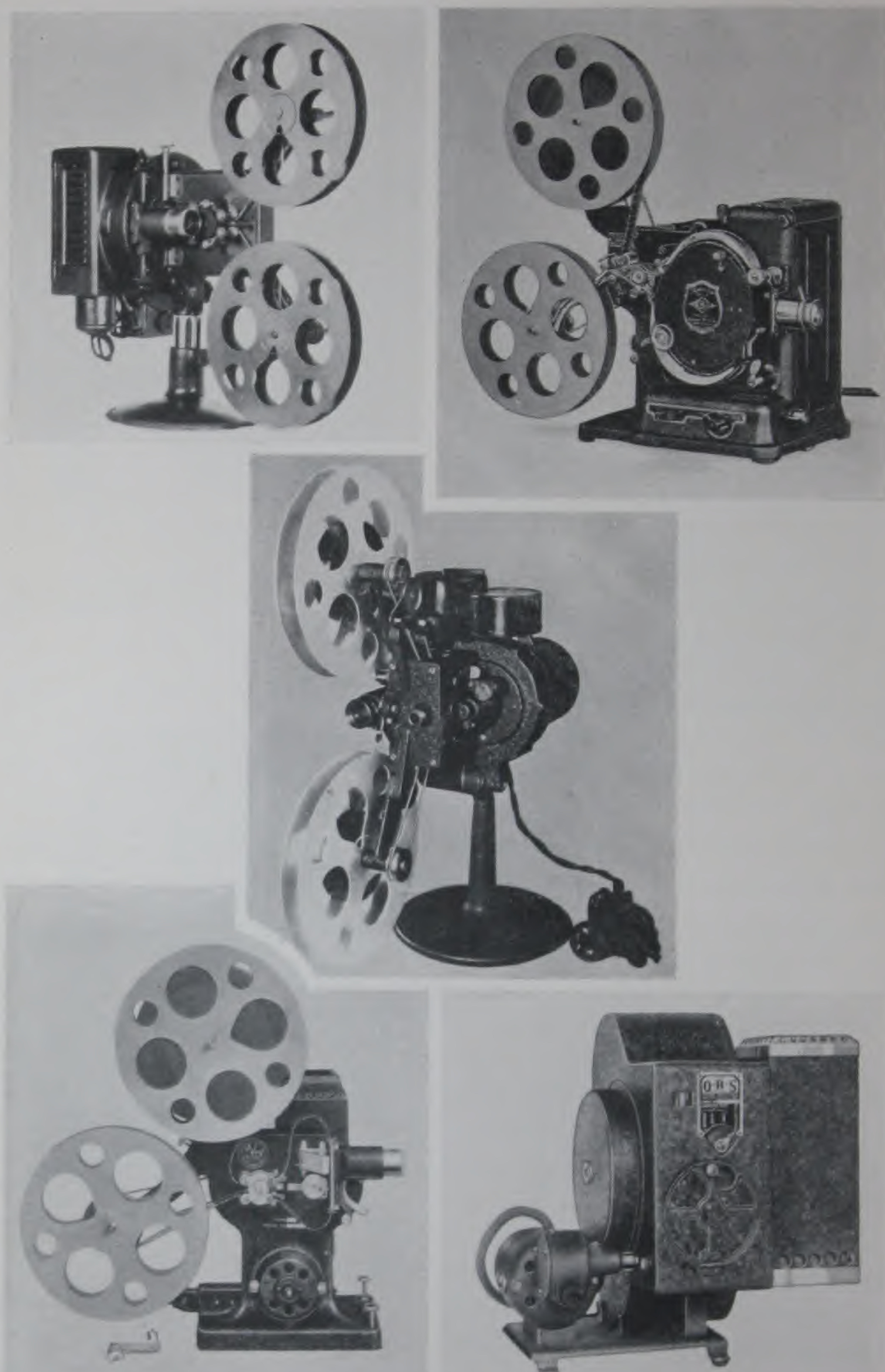
Fig. 3.—A stack of 50 standard glass slides compared with a 50-frame film roll.

a mirrored reflector. Only a small percentage of the light is reflected through the projector lens and the equipment must, therefore, be placed close to the screen,—its application is limited to relatively short projection distances.

Some of the requirements of the several fields are of interest, and are discussed on the following pages.

The Educational Field

The projection requirements of large school or church auditoriums are practically the same as those of the theater. Projection distances to 100 feet or more and 14 to 16-foot pictures are encountered. The quality of projection should be practically on a par with that of the theater, although the work is usually done by one of the students less experienced than the theater projectionist. For the smaller auditoriums and halls, the less expensive semi-portable equipment proves adequate. The 1000-watt, 115-volt lamp is most often used and no auxiliary control equipment is then required. For class rooms and smaller lecture halls, the light weight, compact portable equipments are especially convenient. They may be carried about from room to room as readily as a suitcase and they produce excellent pictures for such locations. The projector using the narrow 16-mm. safety film is found satisfactory for the small class room and, with the wide range of subjects available for



Several of the popular 16 mm. portable motion picture projectors.

films of this width, these little equipments are rapidly increasing in popularity. The equipments employing this narrow film are of especial value to those who wish to take and to project their own pictures.

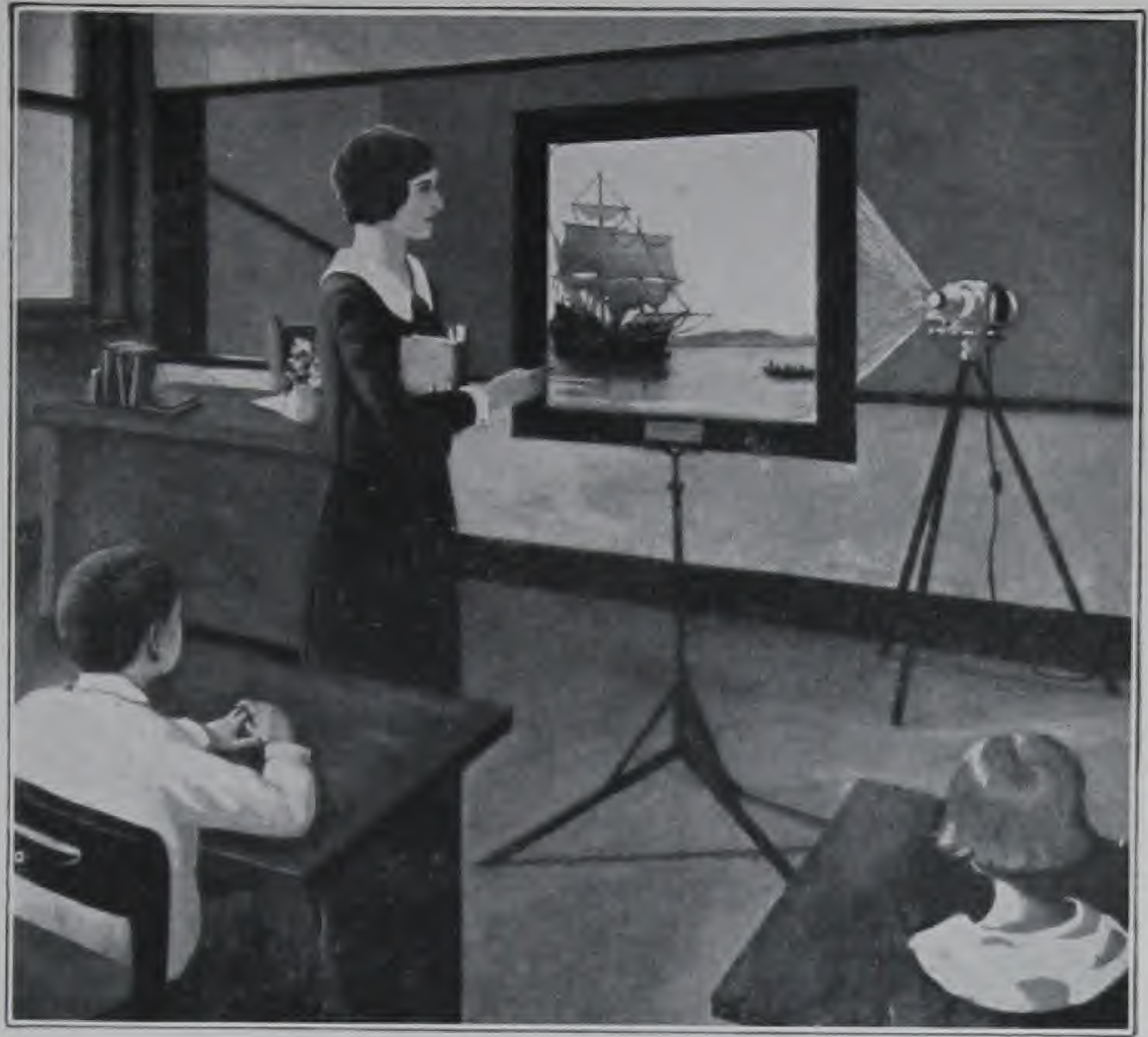
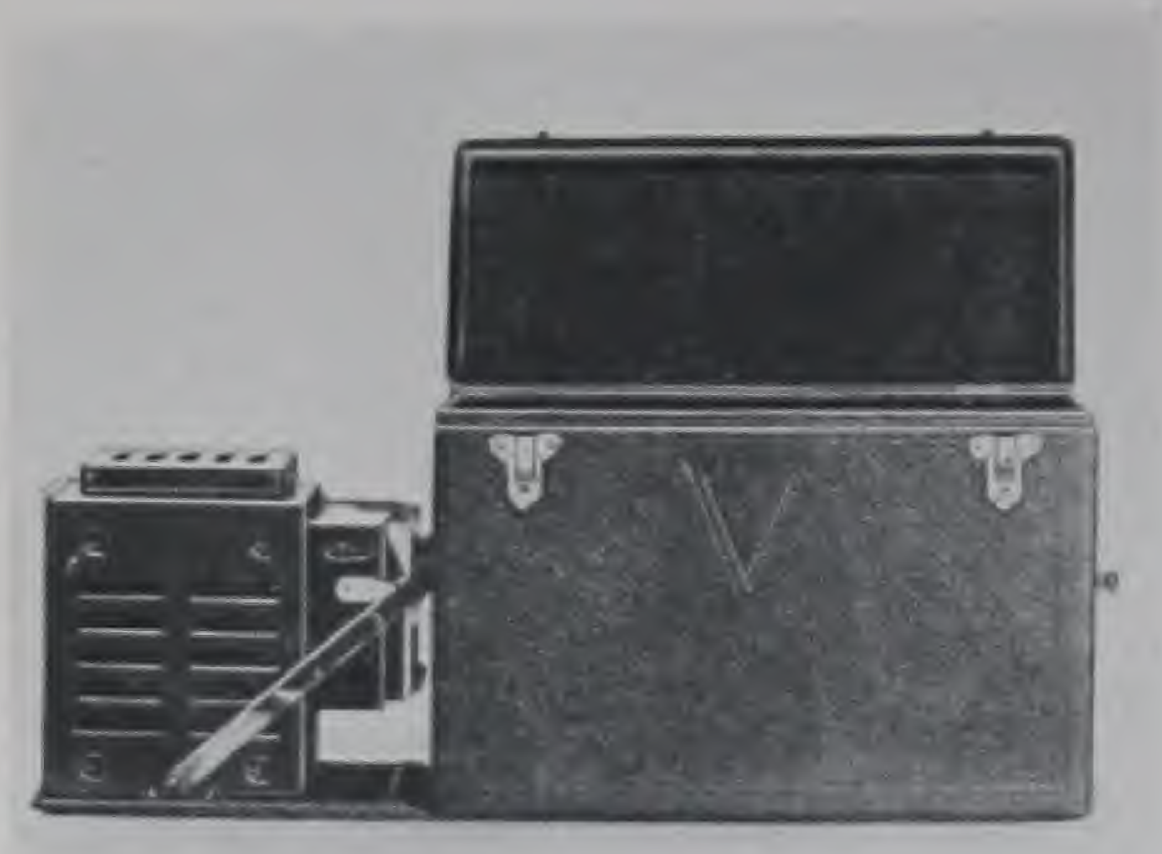


Fig. 4—An ideal class room arrangement, a stereopticon projector and translucent screen.

Some manufacturers of portable projectors, realizing the value of projecting a single still picture to permit detailed study, provide their equipments with filters or other devices which make it possible to stop the film without overheating it. But for many classes of instruction separate lantern slide projectors are needed. For these equipments the 1000-watt, 115-volt lamp provides excellent projection in an auditorium of almost any size. For the class room, Sunday School and average lodge rooms, the 500-watt lamp of this voltage class is sufficient, because relatively less screen brightness is required when the audience is close to the picture.

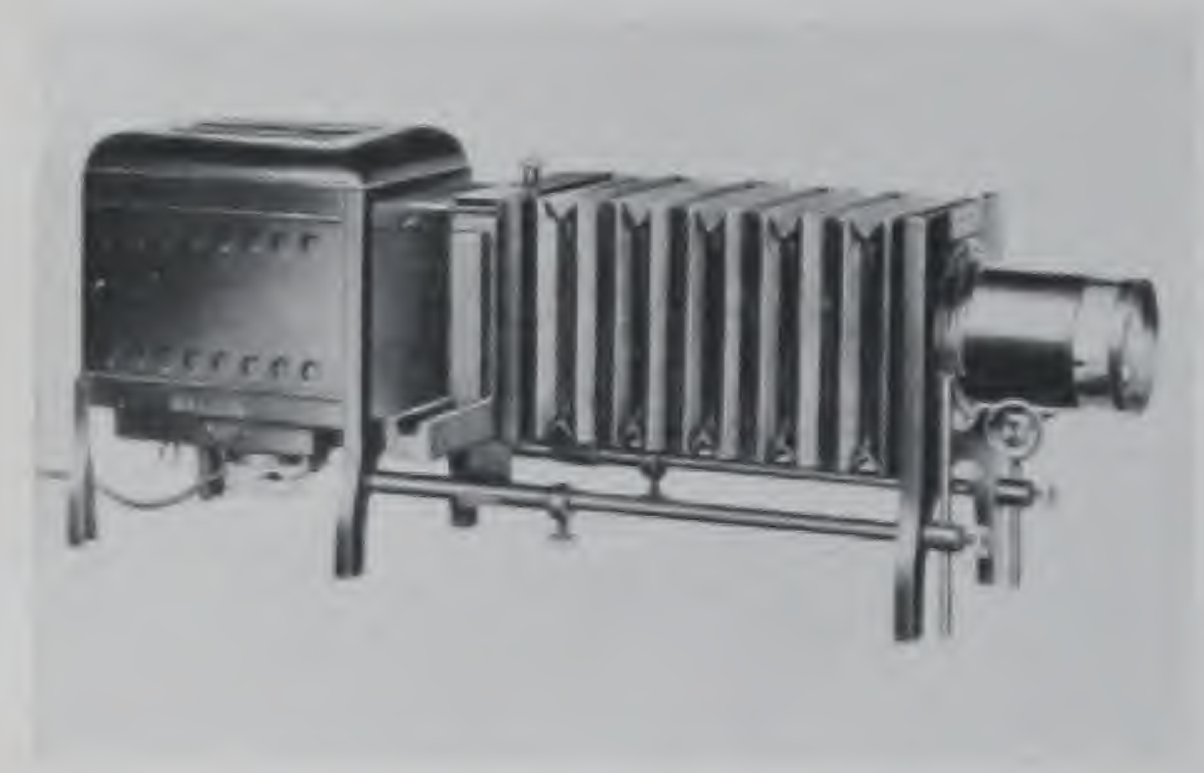
The more compact and easily portable film slide projectors find application in the small class room, although as was stated previously, it is not possible to project as large or as bright a picture as with standard glass slides. Their lower cost, simplicity, low cost of operation, and the possibility of storing a great number of pictures or lecture series of pictures in a small space, are features not to be overlooked in the selection of stereopticon equipment.

The opaque projector has an important application in lecture and class rooms where it is desired to project maps, drawings, postcards, or illustrations from the pages of a book. The 1000-watt lamps are normally required in this equipment when used in the school room, and

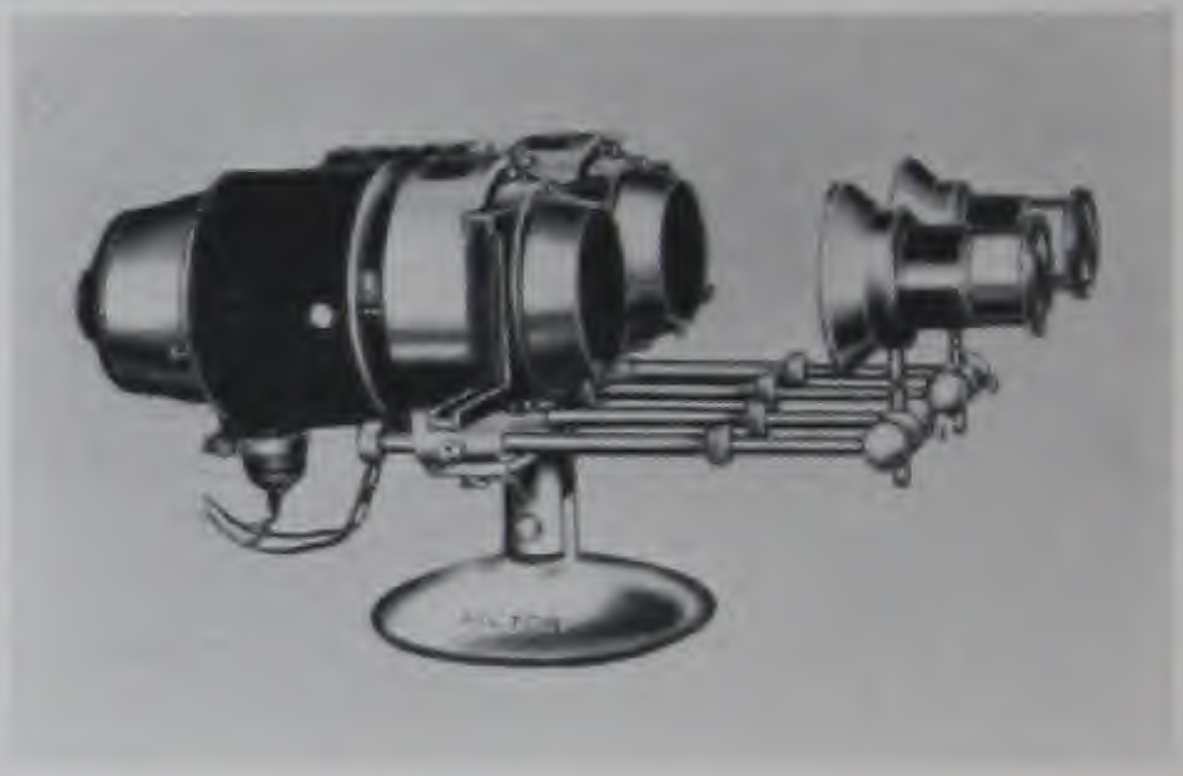


"Suitcase" type stereopticon glass slide.

Combined glass slide and opaque stereopticon



A single glass slide projector



A double dissolving unit

Typical stereopticon film slide projectors.

projection is satisfactory at distances of up to 30 feet. If the translucent type of screen is employed, satisfactory results are obtained with 500-watt lamps, or for larger audiences with the 1000-watt lamps.

The Business Field

Motion pictures of a manufactured product, the manufacturing process, or the application of that product, have proved of great benefit in selling, with the result that many firms are providing their representatives with motion picture film and suitable projectors. Projectors of the portable type using either the 35-mm. or 16-mm. film are light in weight and give screen illumination sufficient for this service.

The compact 16-mm. film projectors, because of their extreme portability and lower cost, are winning much favor in this field. Often a small screen is carried in or attached to the projector carrying case, or a light colored wall serves instead. The illumination available with 16-mm. film equipments is, of course, inadequate for showing pictures to large groups. Here the portable or semi-portable equipments using 35-mm. film must be employed to obtain satisfactory results.

The film slide projectors are also used extensively. Almost an unlimited number of pictures may be conveniently carried with the projector in the small carrying case, or inside the projector itself in the case of the self-contained, or "suitcase" type. Here again, when it is desired to show slides to large groups, the additional illumination obtainable with standard glass slide projectors is needed.

There is an increasing use also of automatic projectors for electrical advertising. Equipments available for this purpose are capable of projecting a large number of pictures or messages in succession. The series may be repeated continuously. Moving letter sign projectors using an endless band of film or tape are also available for this service. These equipments are applicable wherever there is a circulation of people, and are sometimes placed on the top of a building located at a point of high traffic circulation. The attention-compelling power of the motion of one picture being replaced automatically by another is well recognized.

For the lecturer, entertainer or salesmen in locations where no current supply is available, manufacturers have provided a small generator which may be attached to the engine of an automobile. The gasoline-engine-driven generators of the type used for country-home

lighting are also employed, and lamps of the 28-32 volt range used with them. A range of light sources suited to all conditions is available.

Fig. 5—Visual demonstration is a powerful aid in selling.

Home

Much of the fascination of home motion picture entertainment comes from showing pictures of one's family or friends, of the children at play, family picnics, travel and sports. The 35-mm. film is sometimes used for this purpose, but because of the relatively high cost of negative film, positive film, and their necessary development, the narrower 16-mm. width film is now being used almost entirely. There are extensive libraries of 16-mm. film subjects especially suitable for home use, from which films may be rented or purchased at a reasonable price.

By means of a recently introduced simple and inexpensive process, the amateur can now photograph and project his movies in true color. This new development involves the use of three-color filters on the camera and projector, and an ordinary appearing black and white film having minute cylindrical lenses embossed on the surface opposite the emulsion. The positive is obtained by the reversible process. Due to the light absorption by the three-color filters, the color pictures can be taken only in bright sunlight. The projection requirements are similarly greater; the projector must have an efficient optical system and must use a light source of at least 200 watts rating. Since it is not at present commercially possible to make duplicates, these color pictures are employed only in home equipments using 16-mm. film.

Inexpensive opaque, or postcard projectors are especially popular with the children and provide instructive entertainment in the home. The 500-watt lamp provides ample illumination in opaque projectors for this service.

The recently introduced cameras taking "snapshots" on standard 35-mm. motion picture film will probably lead to an increasing use of the film slide projectors in the home. Instead of having prints made on ordinary paper, a roll of positive film can be made from the exposed negative. The snapshots can then be projected to sizable pictures on the screen. Thus an interesting record can be kept of the fishing or camping trip, the vacation or other to-be-remembered experiences. Such a record makes an excellent supplement at low cost to motion pictures taken with the home motion picture camera.

* * * *

Maximum satisfaction is realized when each element in the projection system is designed and adjusted for the incandescent light source. In this bulletin the following subjects are therefore discussed:

1. The optical principles involved in the projection of pictures by means of MAZDA lamps;
2. The properties of the component optical elements;
3. MAZDA lamps and their correct applications;
4. Projector equipment.

PRINCIPLES OF PROJECTION

Optically, apparatus for motion picture projection with MAZDA lamps comprises essentially a light source and condensing lens, a photographic print on a transparent film, a projection objective lens, and a screen, supplemented by a rotary shutter, an aperture plate, and a mirrored reflector. These optical elements are shown in their respective positions in Fig. 6. The optical system of the lantern slide projector differs from that of the motion picture projector in the size and position of the aperture, in the consequent spacing of the elements, and in the omission of the rotary shutter (Fig. 7).

A motion picture projector has, in addition, the mechanism for rapidly bringing successive pictures into position at the aperture and stopping them for a fraction of a second while they are projected as enlargements on the screen. These follow each other so rapidly (usually at the rate of about twenty per second) that the eye does not distinguish

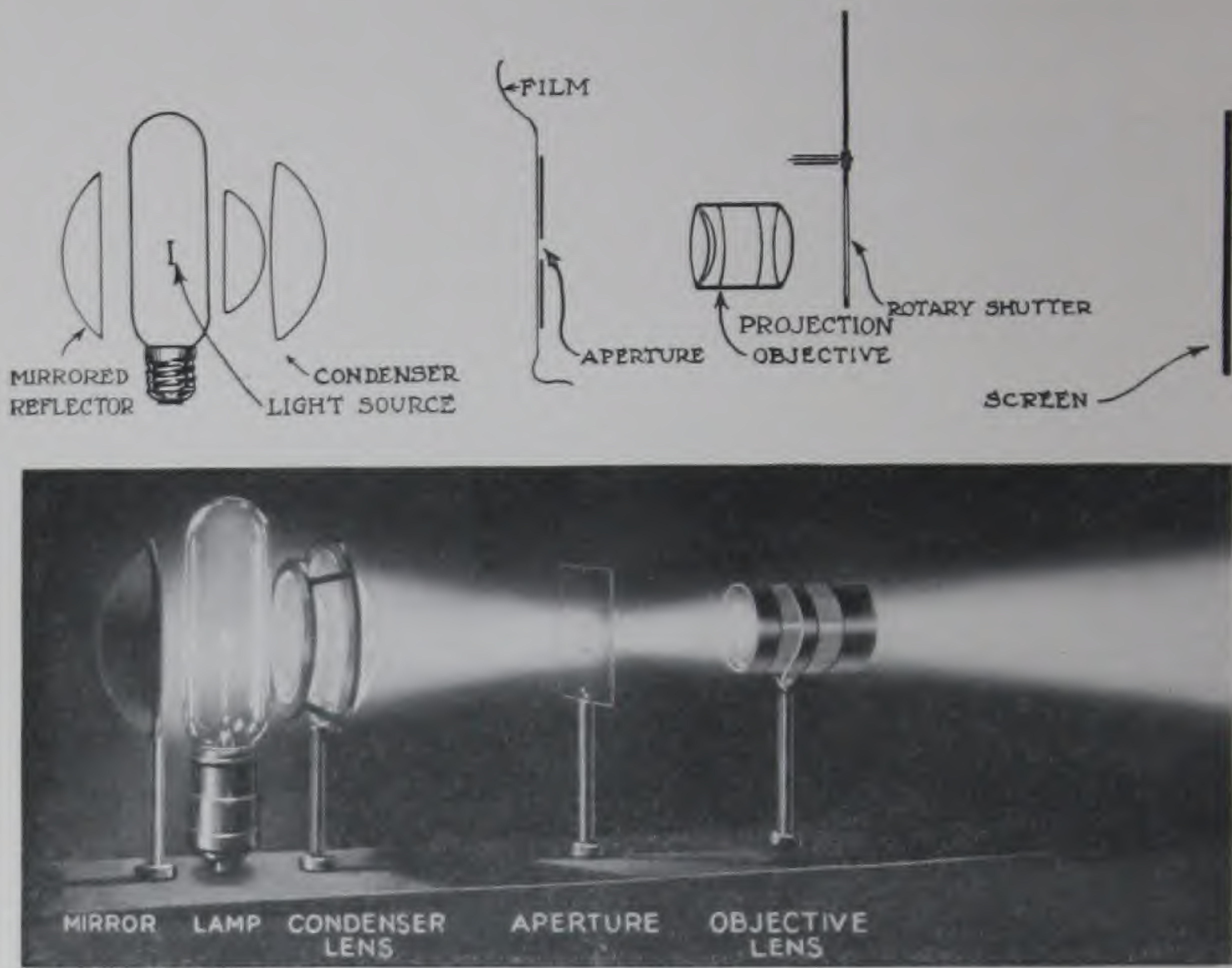


Fig. 6.—Essential optical elements for motion picture projection with MAZDA Lamps.

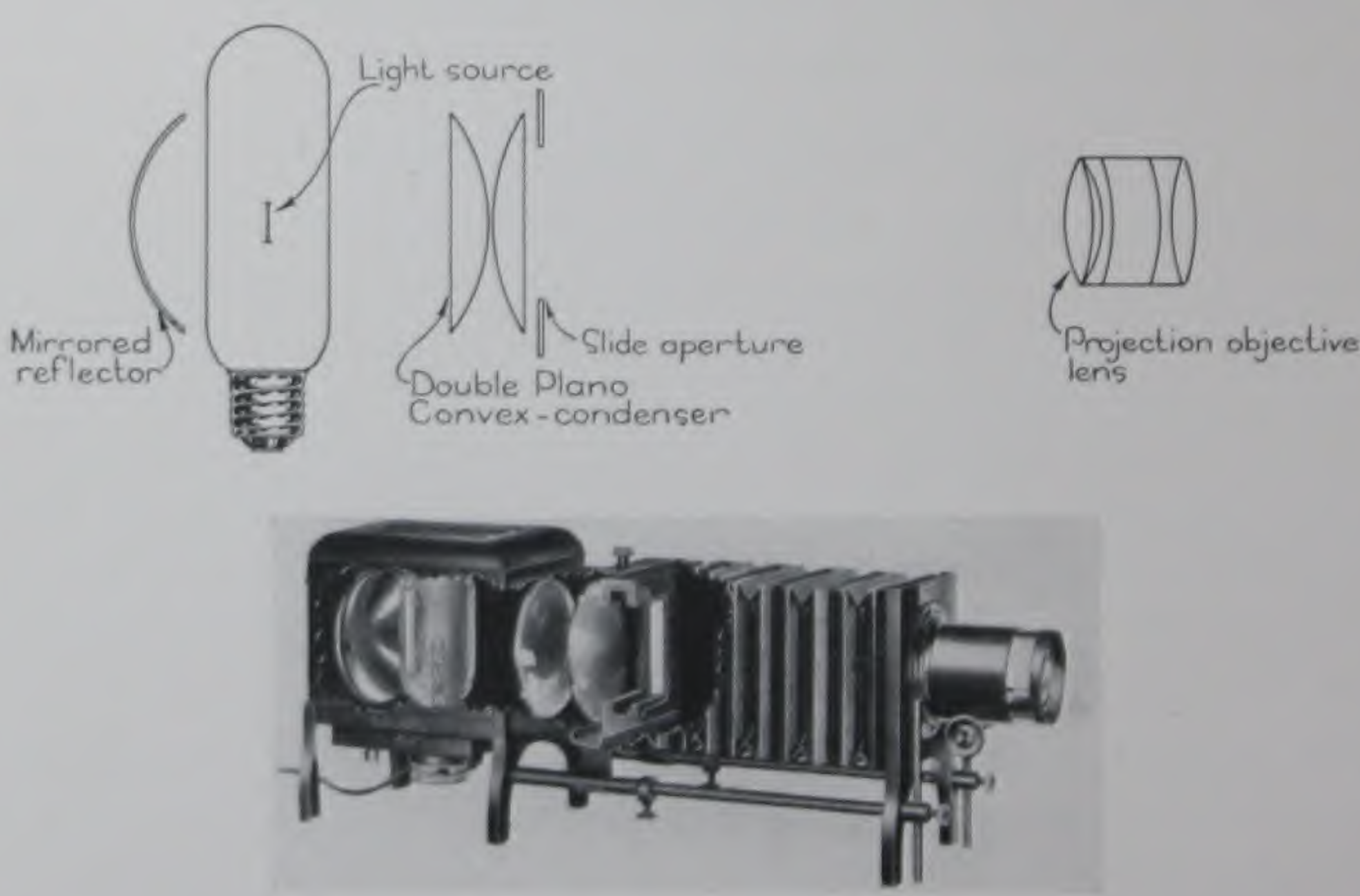


Fig. 7.—The optical elements of a stereopticon projector.

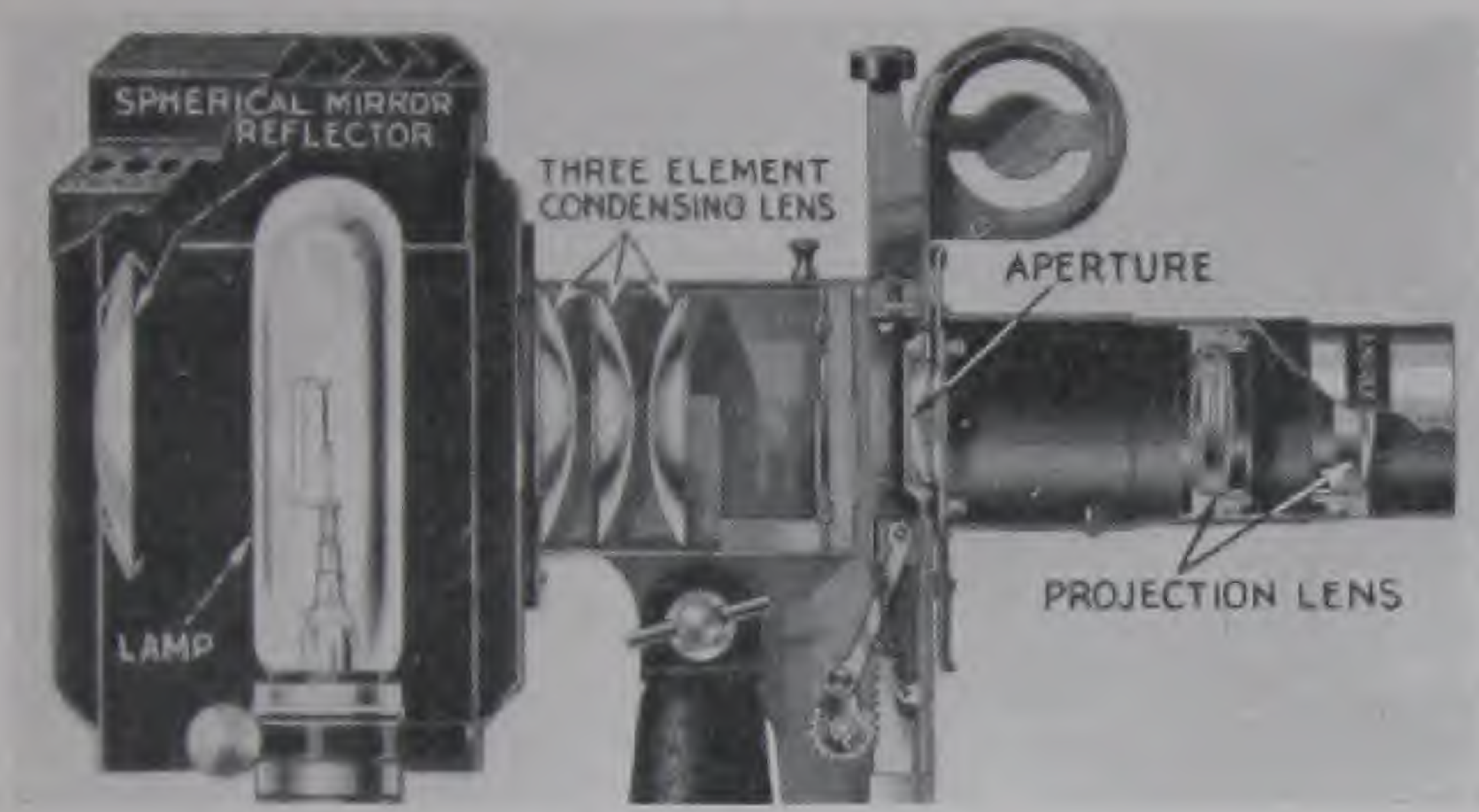


Fig. 8—Optical elements of a film slide projector.

individual pictures, but apparently beholds the motion in the scene photographed.

The refractive properties of glass, that is, the power to bend light rays and control their direction by the contour of the glass surfaces, are utilized to direct the rays from each point on the picture to a corresponding point on the screen. This operation, resulting in a defined image, is known as focusing. The combination of glass elements used to accomplish focusing is known as a projection objective lens. Such a lens produces an image only in one plane and its distance from the lens depends upon the contour of the glass surfaces, as well as upon the distance between the object and the lens. (See Fig. 9.)

The area of the image on the screen in motion picture theaters is usually from 25,000 to 60,000 times that of the print on the film. Moreover, the projection lens absorbs some of the light, and nearly one-half of the remainder is absorbed by the rotating shutter, with the result that the quantity of light passing through a unit area of the film, even when all of it is directed to the objective, must be from 70,000 to 170,000 times that received by each unit area of screen.

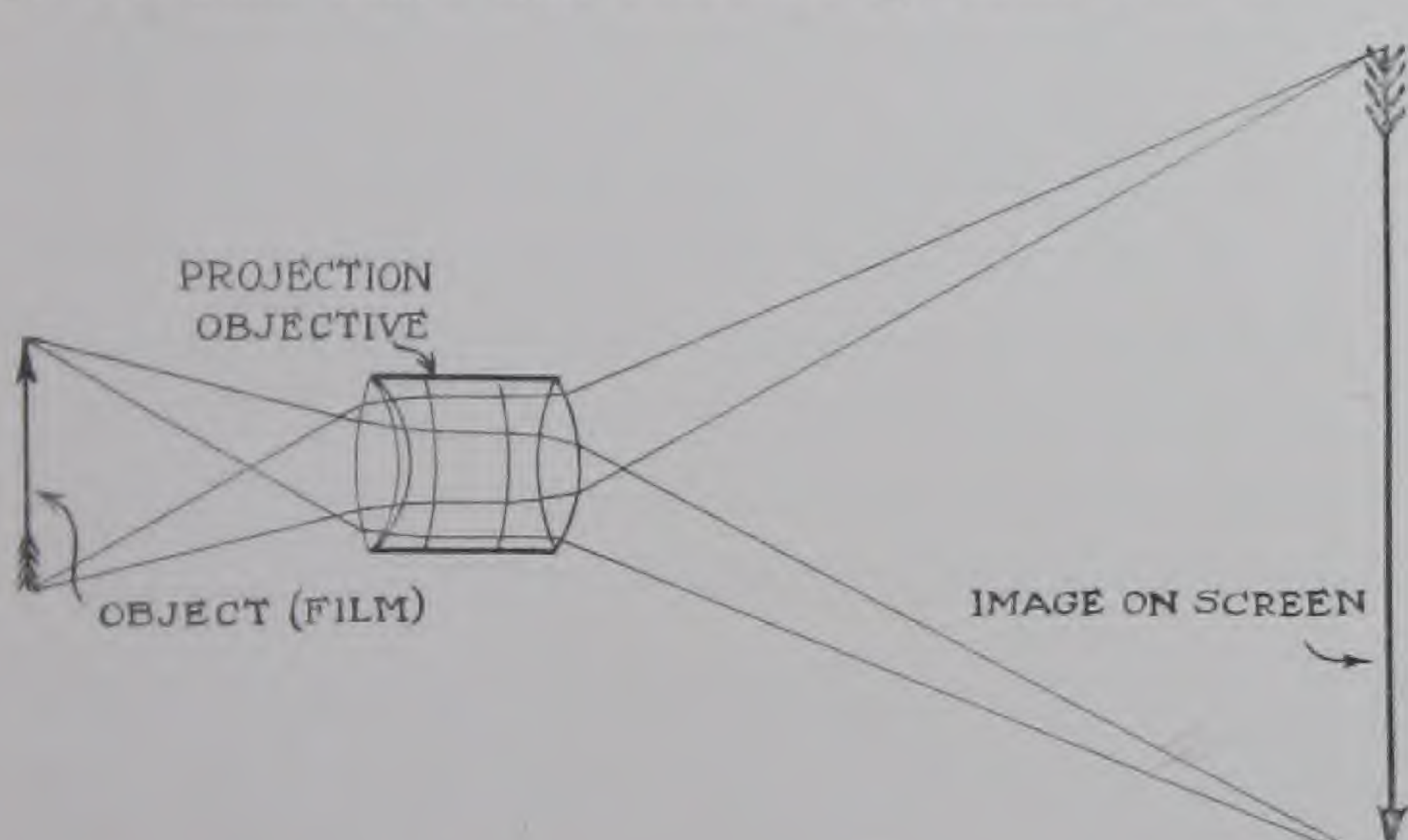


Fig. 9—The Projection Lens — Light reaching any part of the lens from a single point on the arrow is focused at only one point on the screen.

In order that a given point on the screen may be illuminated and an image formed, light source area must be disclosed on looking back from this point through the projection lens and a corresponding point in the film. In order that the illumination over the entire screen may be uniform, equal areas of light source must be disclosed from each point on the screen. Inasmuch as the light rays cross, so that, for example, the upper part of the film is projected to the lower part of the screen, the apparent area of light source provided must be greater than that of the film by an amount depending upon its distance behind the film. Thus the source *AB* of Fig. 10 would be of sufficient size.

It happens that there are no sources which of themselves direct more than a small percentage of their light into the small angle included by the projection lens. Moreover, the heat radiated and conducted from the source in Fig. 4 would unduly raise the temperature of the film and its guides. Here again the refractive properties of glass may be employed to intercept the light emitted through a wider angle from a small source placed back from the aperture and to direct it through the film to the projection lens. By the proper design of the curvature of the faces of such a condensing lens it can be made of relatively large diameter with respect to the source dimensions and thus become both a large apparent source and a means of utilizing a large amount

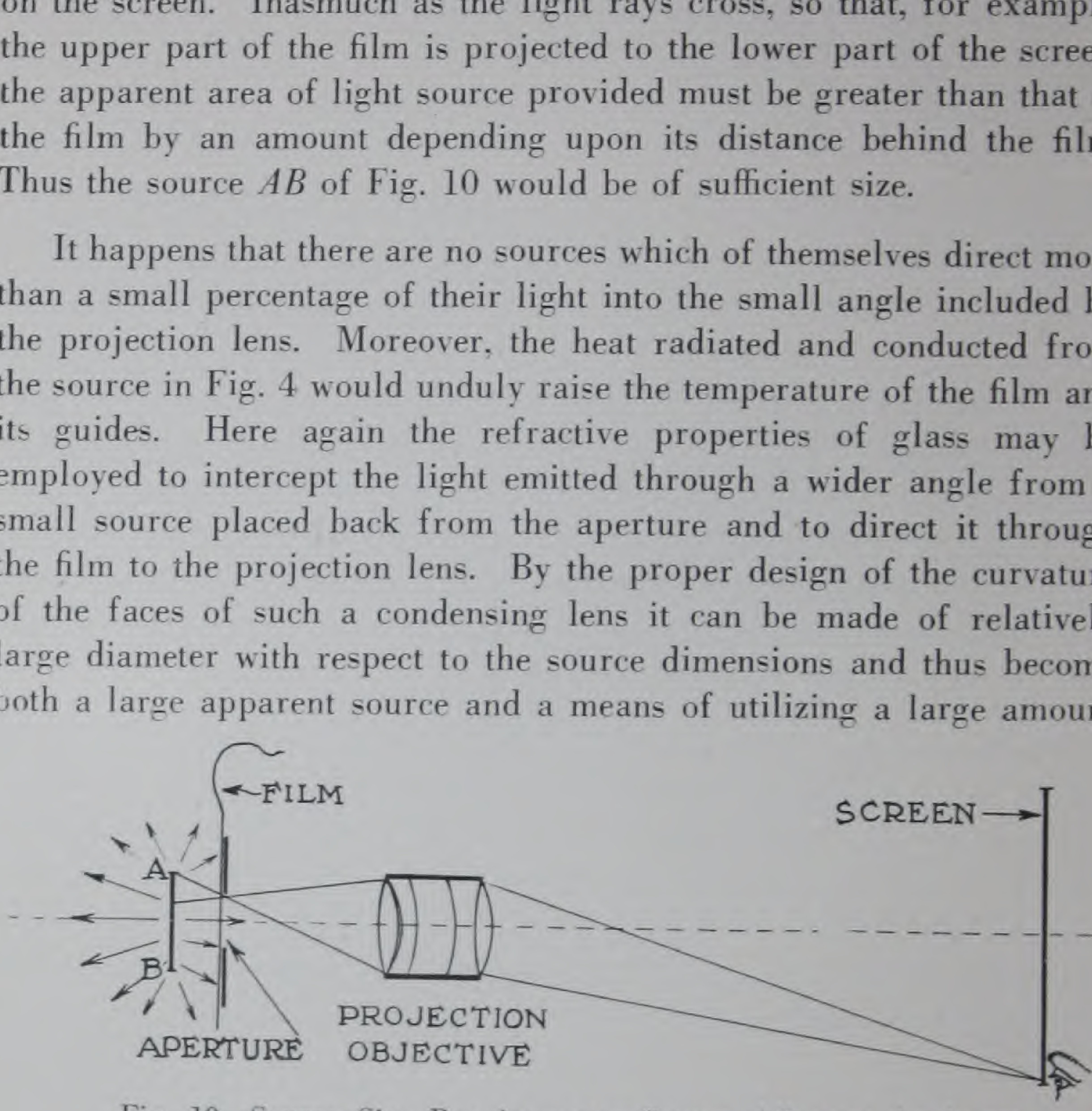


Fig. 10—Source Size Requirements—Source AB must be larger than the aperture to send light through a point at the edge of the aperture and through the full opening of the objective lens.

of the total light flux. The diameter of the condensing lens for various distances from the film is determined by the requirement that for uniform screen illumination equal areas of the lens must be visible through the optical system from all points on the screen (Fig. 11).

The converging beam from the condenser forms an image of the source at the point where the rays cross; as this image is at or near the narrowest part of the beam the aperture should be placed at this point

in order that the greatest amount of light may pass through it, for with sources employed in practice the cross section of the converging beam from the condenser is, even at its narrowest part, usually equal to or greater than the area of the film. If the source is not of uniform brightness, the film placed at this position will not be evenly illuminated. Such a case is that of the incandescent lamp with the several filament coils separated by narrow spaces; however, if a spherical mirrored reflector is placed with its center of curvature approximately at the source it may be adjusted so that the images of the coils fall in the non-luminous spaces. The source then becomes in effect sufficiently uniform to permit the aperture to be placed close to the image position.

By the addition of the mirrored reflector a much larger proportion of the light from the source is utilized.

The aperture plate is a metal plate with an opening slightly smaller than a single picture of the film, and serves to limit the light beam to the single picture being projected.

With the intermittent mechanism commonly employed for moving the film, the picture is in movement from one-fourth to one-fifth of the time. When twenty pictures are projected per second, this means that approximately one hundredth of a second of movement is followed by

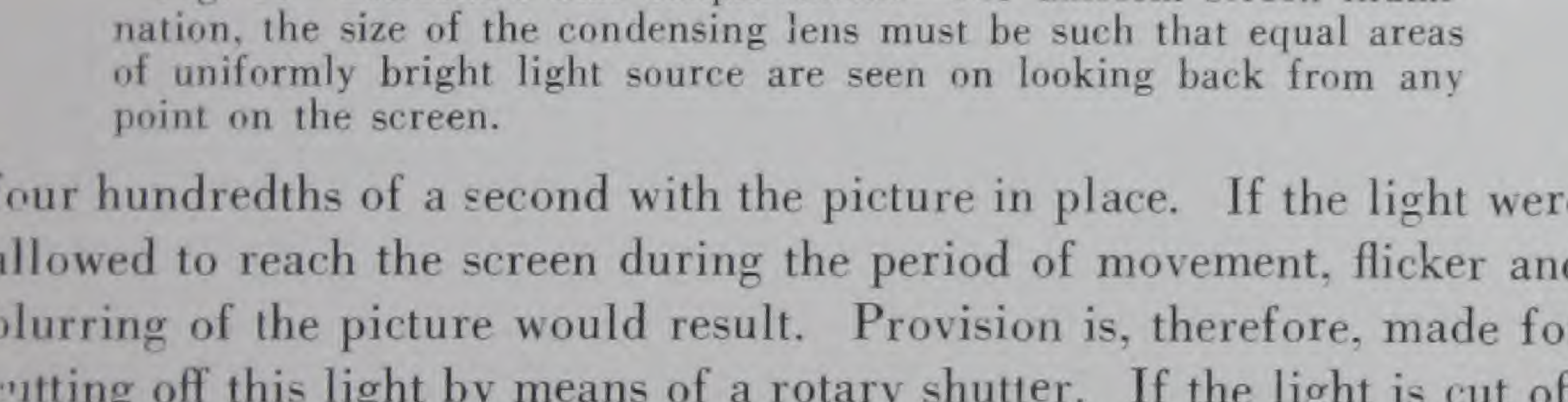


Fig. 11—Condenser Size Requirements—For uniform screen illumination, the size of the condensing lens must be such that equal areas of uniformly bright light source are seen on looking back from any point on the screen.

four hundredths of a second with the picture in place. If the light were allowed to reach the screen during the period of movement, flicker and blurring of the picture would result. Provision is, therefore, made for cutting off this light by means of a rotary shutter. If the light is cut off twenty times per second, blurring can be obviated but flicker persists. Rotary shutters are, therefore, employed with two or three blades, so connected with the mechanism and of such width as to cut off the light from the picture while it is in motion and to interrupt the light similarly at regular intervals in between. With these higher frequencies of interruption, flicker is substantially eliminated.

PROPERTIES OF THE COMPONENT ELEMENTS

Light Source

Since the 35-mm. film aperture and projection lens present openings of considerable area, there is no necessity for keeping the light source unduly small. The maximum size of source which can be employed effectively with a given optical system is dependent on the refracting power of the condensing lens, the size of the aperture opening, the size of the projection lens, and the distance of the aperture from the condensing and projection lenses. A source of size *AB*, Fig. 12, projects a beam *A′B′* at the aperture, all of which passes through; the larger source *CD* will send a greater amount of light through the opening, but the source *EF* produces a beam *E′F′* at the aperture so large that but a small part passes through and the remainder of the light is wasted.

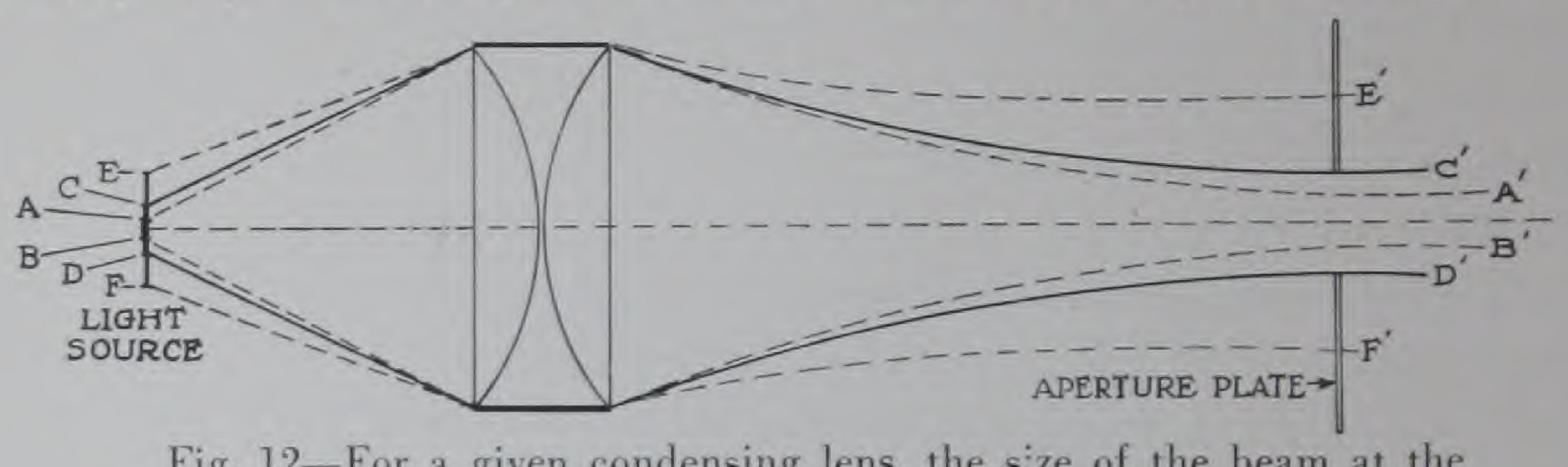


Fig. 12—For a given condensing lens, the size of the beam at the aperture plate is proportional to the size of the light source.

The curve of Fig. 13 shows the characteristic relation between source size and screen illumination of an optical system commonly used in motion picture projection. If the energy required for the source is in

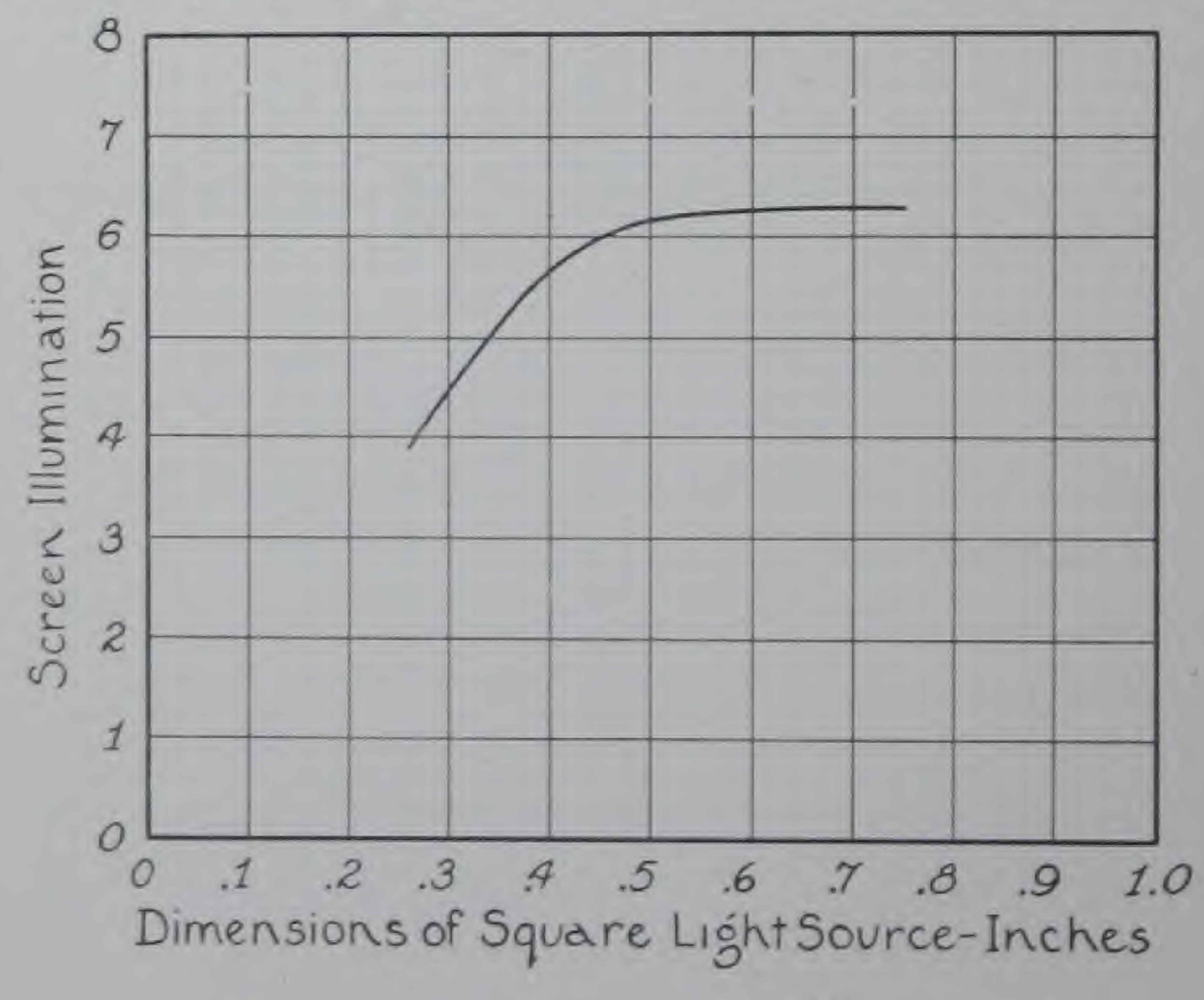
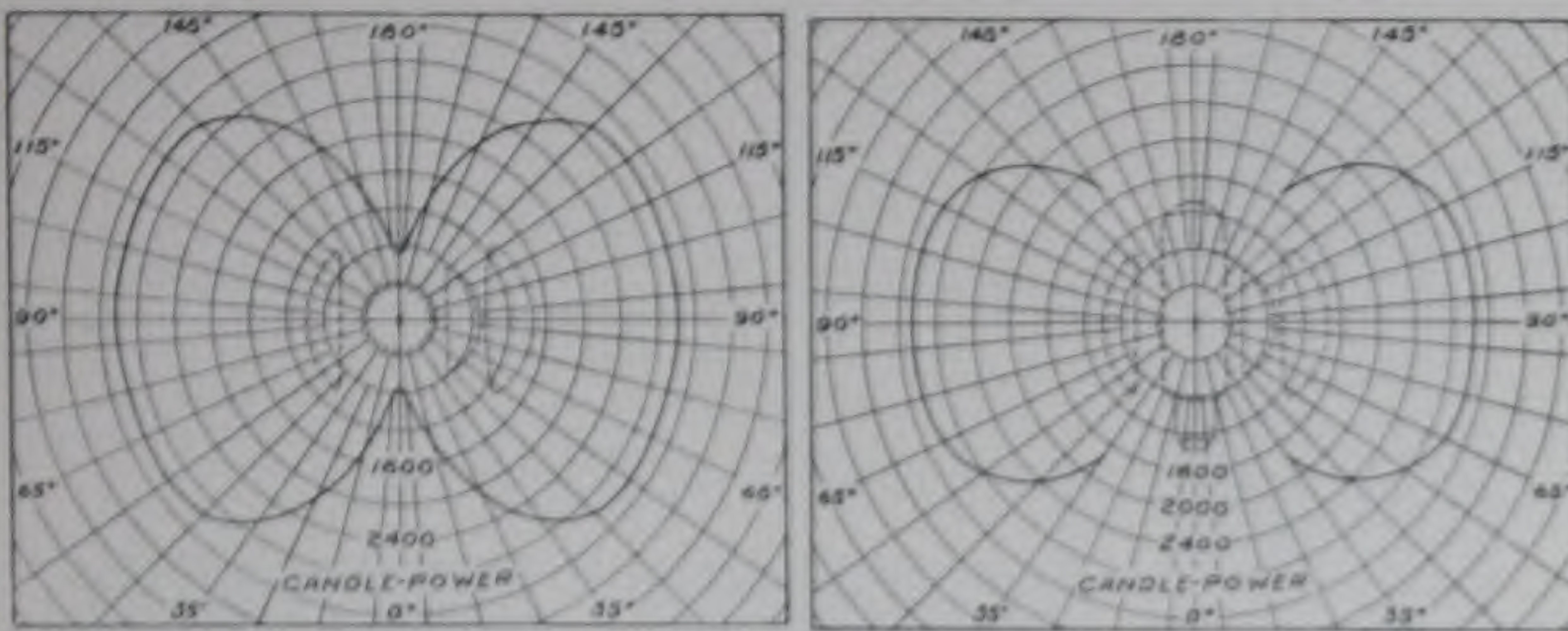


Fig. 13 — Characteristic relation between source size and screen illumination for an incandescent lamp motion picture projector using 35-mm. film. Source of uniform brightness—wattage increases with light source area.



Curve A Curve B

Fig. 14—Light distribution from 900-watt, 30-ampere MAZDA lamp. A—Distribution in horizontal plane. B—Distribution in vertical plane.

proportion to the source area, it is evident that each increment in screen illumination is obtained at an increasing cost for energy.

The light source in the MAZDA lamp for picture projection consists of parallel segments of coiled tungsten wire. The use of a heavy wire (high current, low voltage) permits more source surface to be placed within the useful source area than is possible when smaller wire sizes (lower current, higher voltage) are used. With the coils aligned in one plane at right angles to the optical axis (the line through the center of the optical units), the light can be most effectively controlled. The distribution curves of Fig. 14 show that the maximum candlepower and a large percentage of the total light can be directed toward the condenser and mirror, and the amount escaping at the sides kept small.

In order to prevent short-circuiting of the filament coils they must be separated, and it is this separation that breaks up the uniformity of the light source and makes necessary the filling in of these spaces by the use of a mirrored reflector.

Mirrored Reflector

A mirrored-glass spherical reflector, Fig. 15, is placed behind the lamp so that the filament is at the center of curvature. It turns back about 80 to 85 per cent of the light striking it. The greater part of this light is brought to a focus in the plane of the filament as an inverted and reversed image of the filament. The mirror is moved just sufficiently to one side to permit the image of the filament to dovetail with the segments of the filament itself, as is shown in Fig. 16-b. With the mirror adjusted in this way, most of the reflected light flux travels to

Fig. 15—Mirrored glass spherical reflector for use with 900-watt MAZDA Lamps. Diameter, $5\frac{1}{4}$ inches; outside radius of curvature, $3\frac{3}{8}$ inches.

the condenser in directions that permit the condensing lens to refract it with the beam from the filament itself.

Two important advantages result: (1) the screen illumination is increased from 50 to 75 per cent, and (2) the source becomes in effect a solid luminous rectangle, and evenness of screen illumination is thereby obtained.

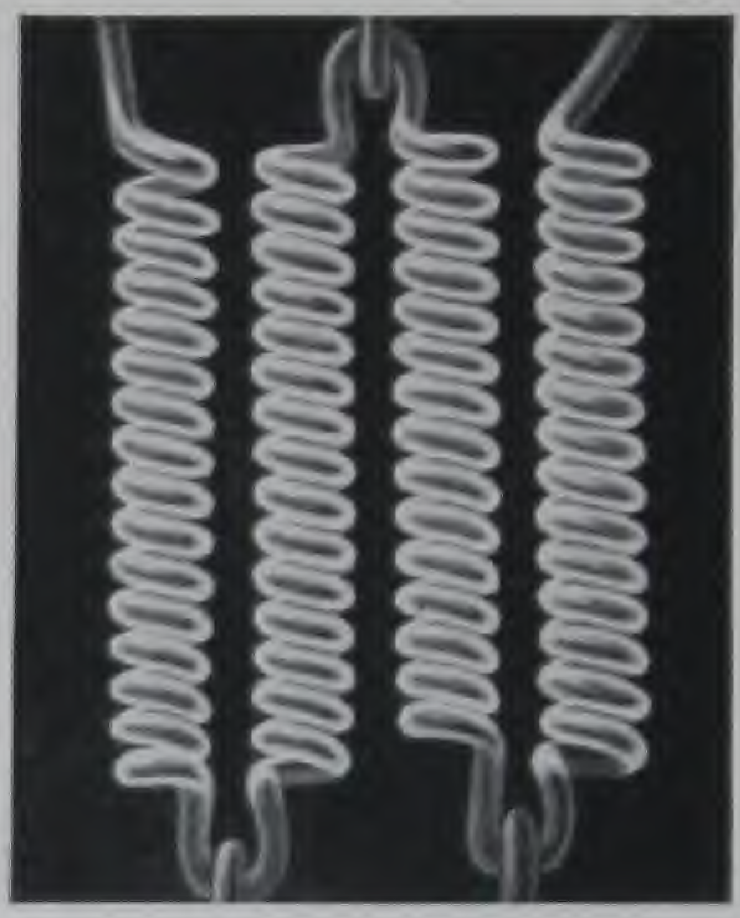


Fig. 16-a—Filament of the 900-watt MAZDA Lamp for motion picture projection (about twice normal size).

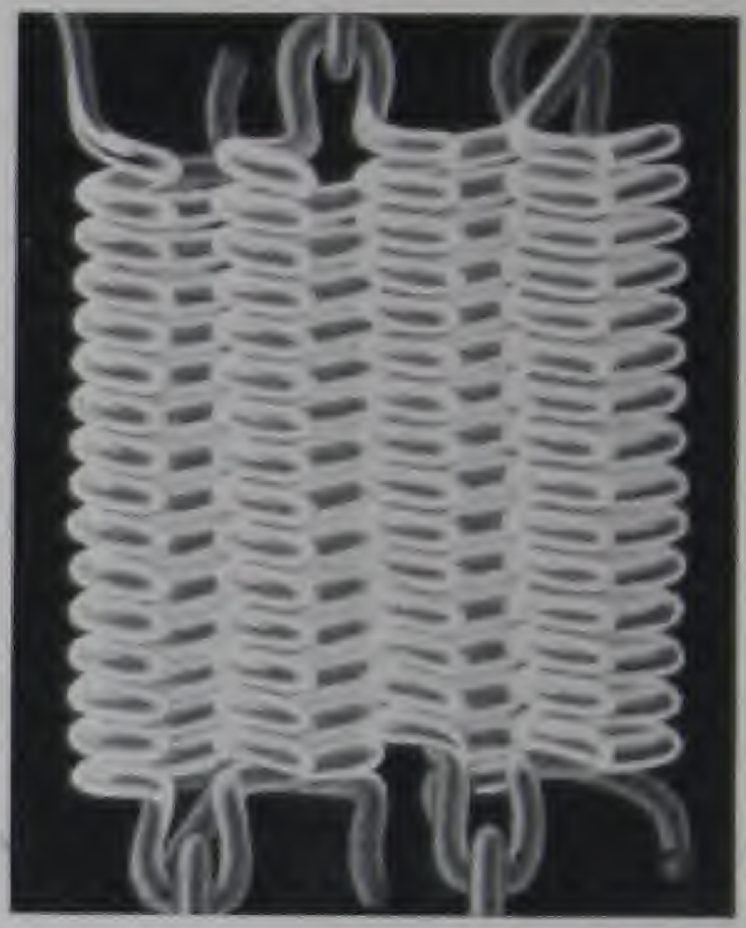


Fig. 16-b—The reflected image of filament segments intermeshed with the coils.

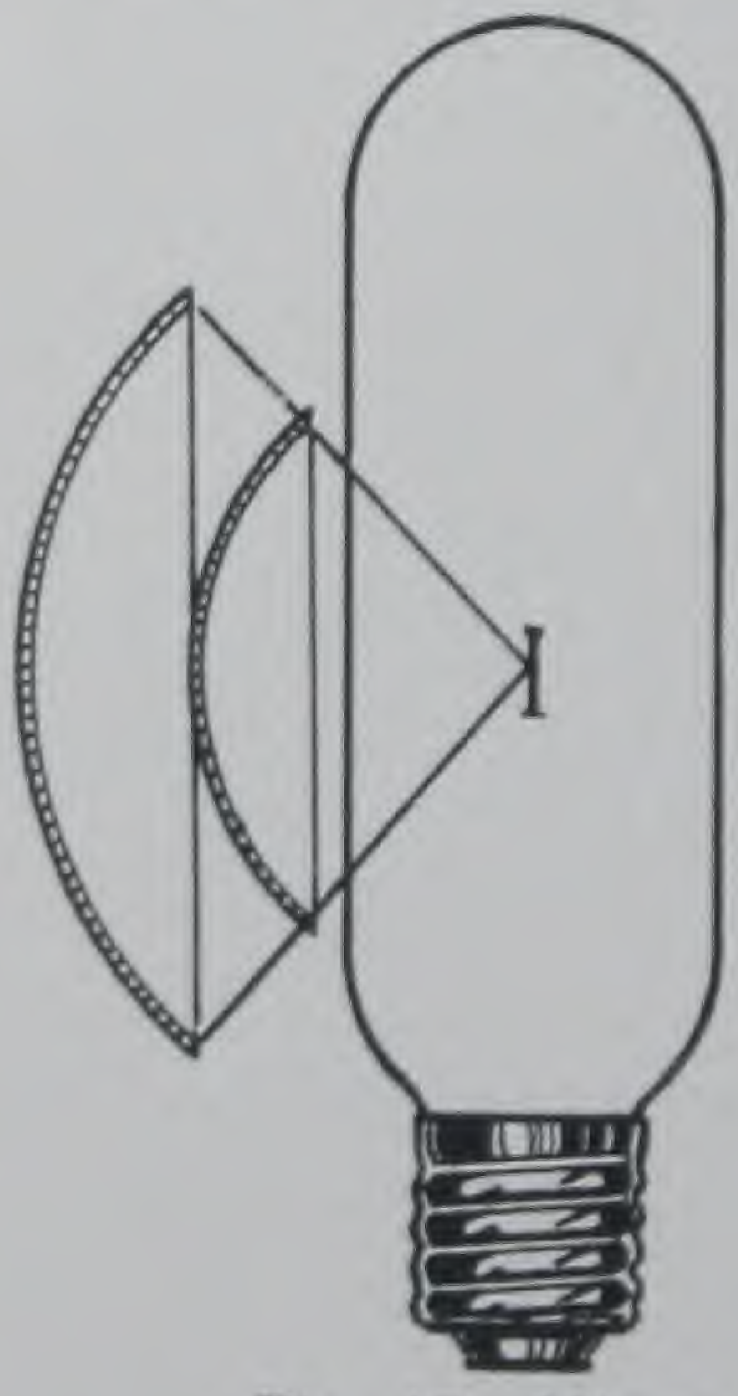


Fig. 17—Mirror Size—To intercept the same amount of light flux the diameter of the mirror must increase proportionately with the radius of curvature.

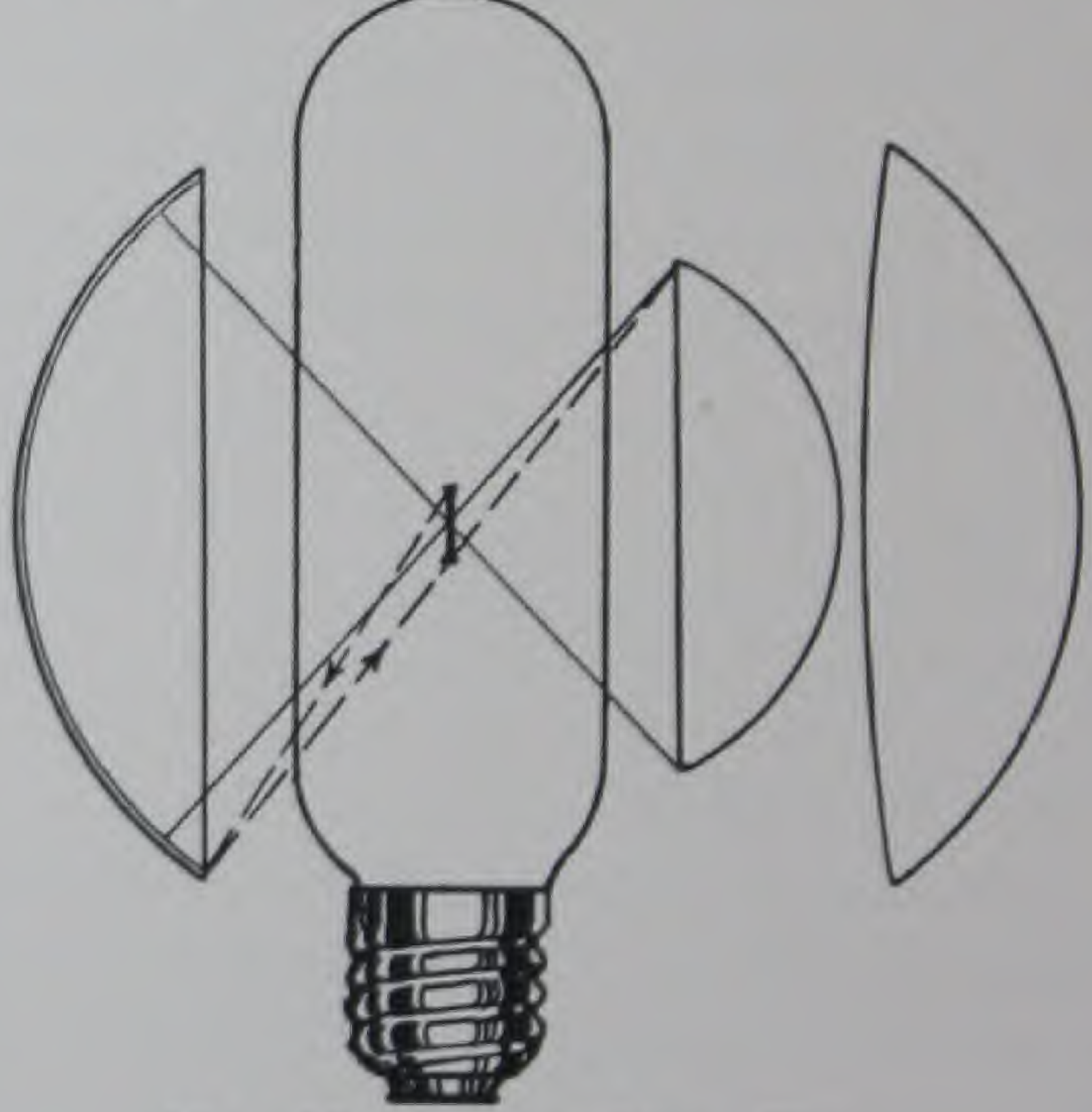
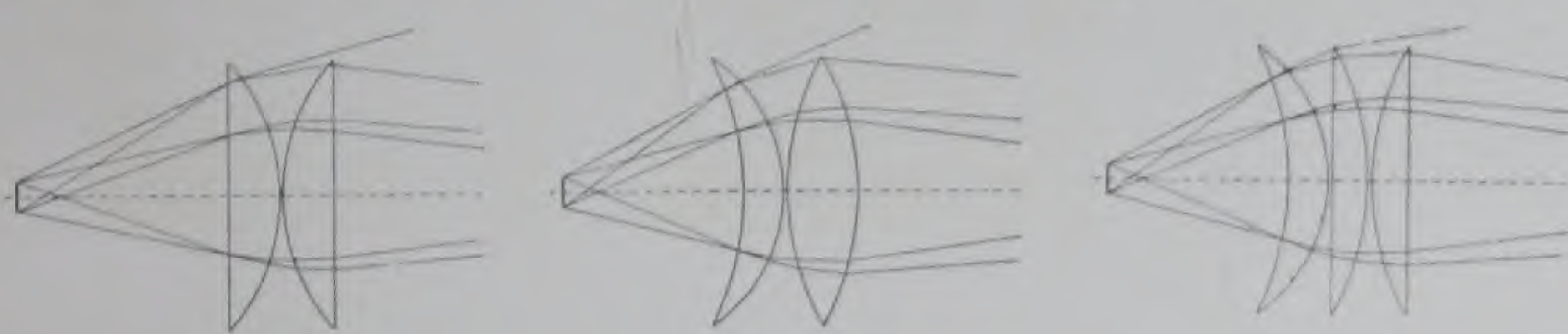


Fig. 18—Mirror Size—The condenser will redirect light from a reflector which intercepts a larger angle of light than does the condenser.

In order that a maximum percentage of the light may be utilized, the plane angle subtended by the mirror should be from 15 to 20 per cent greater than that subtended by the condenser. The diameter required to intercept this angle is relatively small if the mirror is placed close to the lamp, but the mirror is then subjected to considerable heating from the lamp with consequent danger of rapid deterioration. With mirrors of less curvature and correspondingly increased diameter, not only is the surface farther from the hot lamp but there is greater area provided for dissipating the radiant heat which it absorbs.

Condensing Lens

As was stated above, the condensing lens is a device for intercepting a large solid angle of the light emitted by a lamp placed some distance



A B C

Fig. 19—Types of condensing lenses applicable for both motion picture and lantern slide projection. A—Double Plano-Convex; B—Meniscus—Bi-Convex; C—Meniscus—Double Plano-Convex.

from the film or slide aperture and redirecting it through the aperture to the projecting lens and screen. It is evident that the larger the diameter of a condensing lens of a given refracting power, the more light it will pick up.* But with increased diameter the thickness also becomes greater, and very thick lenses which are ground to spherical surfaces cause spherical aberration, that is, they bend these light rays near the edge more than those through the central part. A moderate amount of spherical aberration is an advantage in motion picture projection in that it tends to break up the source image and thus improves screen uniformity, but if it is so marked that a considerable part of the light is

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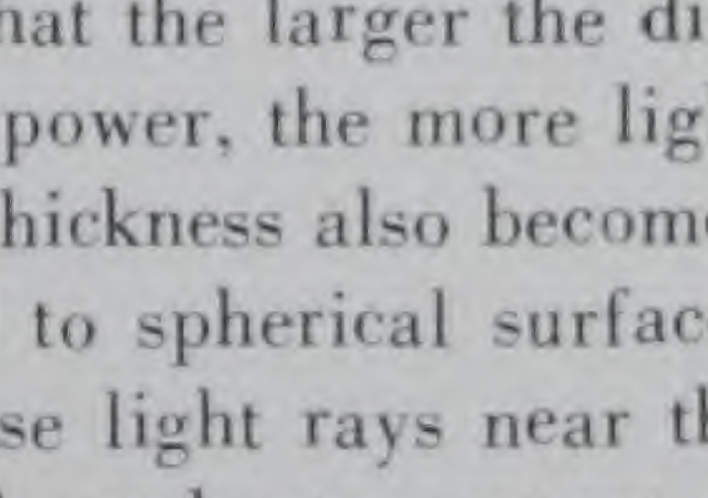
*When parallel rays of light are intercepted by a lens, they are so bent as to pass substantially through a point some distance beyond the lens, which point is called the focus. The shorter the distance from the center of the lens to the focus, i.e., the shorter the focal length, the greater is the refracting power of the lens.



directed outside the projection lens, the gain in light intercepted by the greater diameter is soon lost. To minimize the spherical aberration two or three thin lenses may be used in combination instead of one thick lens.

Another successful method is to use lenses with surfaces ground to a contour other than spherical in order to control the light more accurately. These aspheric condensing lenses have a higher refracting power than has been achieved in any other type; thus for a given diameter of lens they are made of shorter focal length with a large resulting increase in the amount of light intercepted. Spherical aberration is reduced to a negligible quantity; hence the interval along the optical axis through which there is an image of the source is very short and the aperture may be placed close to the narrowest point in the beam with high utilization of the light.

Fig. 20—Aspheric condensing lens combination.

A third but less efficient method of minimizing aberration is to cut away some of the glass of a thick lens as in the modified Fresnel lens shown in cross section in Fig. 21. Here, in a single piece of glass are five relatively thin central prisms surrounding a double convex lens. The Fresnel or prismatic lens has an advantage over the conventional combination of two spherical plano-convex lenses of similar refracting power in that the contour of the several prism surfaces can be designed so that the light from each ring is directed to a different part of the film. Thus the light source is focused at different distances from the condenser with the result that at the aperture no well defined source image appears, and uniform illumination of the film is obtained. The gain in refracting power is to a considerable extent offset by a loss of light, since with the extended light source and with the rounded edges of the prisms characteristic of a pressed lens, some of the rays strike the risers of the

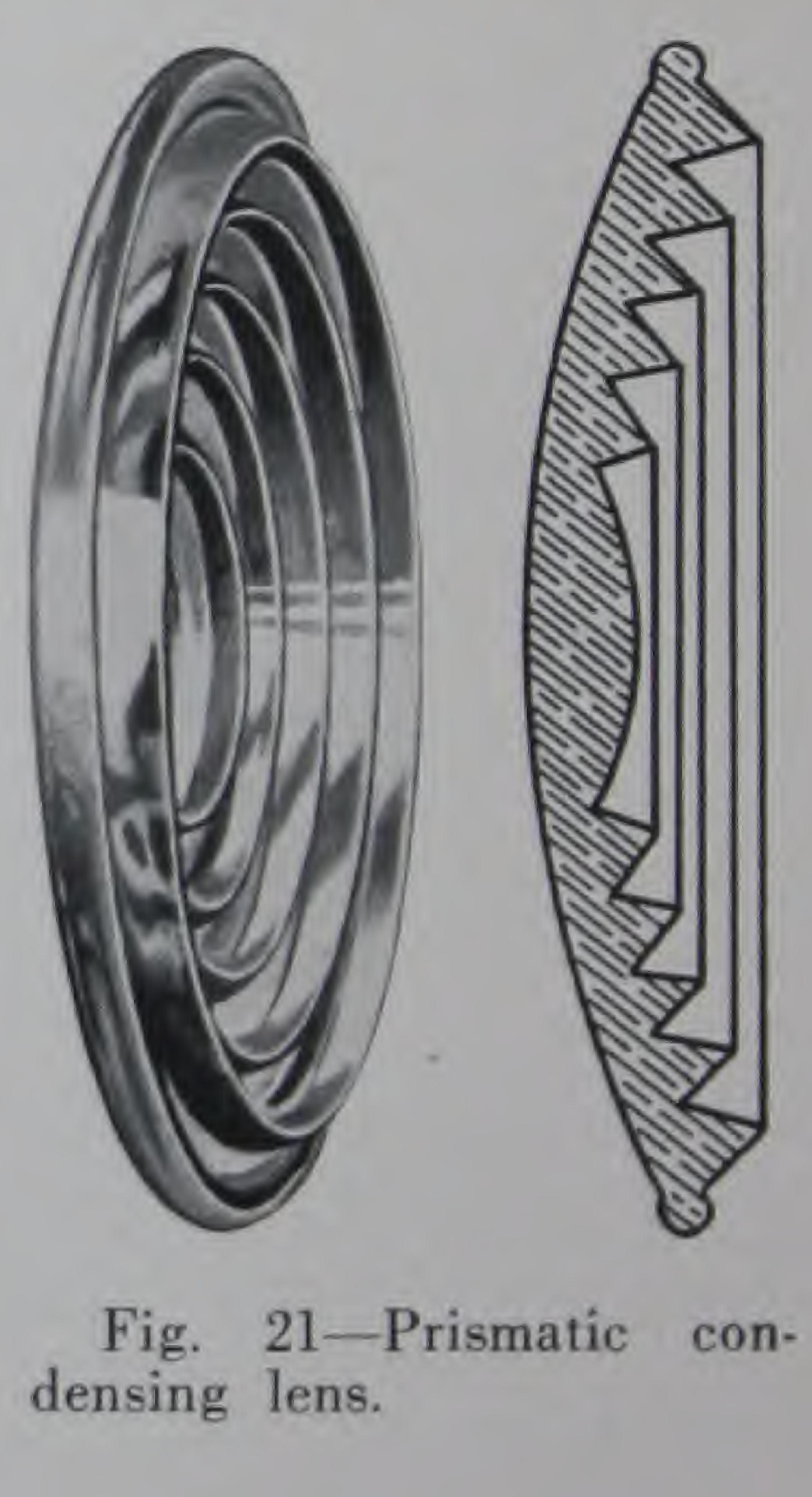


Fig. 21—Prismatic condensing lens.

prisms and are refracted at such angles that they cannot be used. This loss, together with the absorption and the surface reflection, is of the order of 30 per cent.

Each element of a condensing lens of other than the prismatic type will cause a loss through absorption and reflection of approximately 10 per cent of the incident light. Most of this is due to reflection at the surfaces, which varies with the angle of incidence. The loss by absorption is of the order of 3 to 6 per cent per inch of thickness. In a well designed three-element combination consisting of a meniscus and two plano-convex units there is a loss of about 30 per cent; but where the elements are of the same diameter, as is more often the case, there is an additional loss due to the fact that the second lens does not intercept all of the diverging rays issuing from the one nearest the light source. (Fig. 19.)

Fig. 22—Spherical Aberration—that part of a thick spherical lens near the edge refracts the light through a greater angle than does that near the center.

As light passes through a lens the rays of different colors are bent through slightly different angles, so that from any small area of the lens the refracted light spreads into diverging rays of the different spectral colors. This phenomenon is known as chromatic aberration. Except at the edge of the beam, or where there is a sharp contrast with the background, as in the case of the outlines of objects in the image, these several colors superimpose and blend together. A projection lens must be essentially free from chromatic aberration; but in the case of condensing lenses, the projection of these colors to the screen can be avoided by intercepting the edge of the beam and using a lens of such design that the lamp filament is not focused as an image at the aperture.

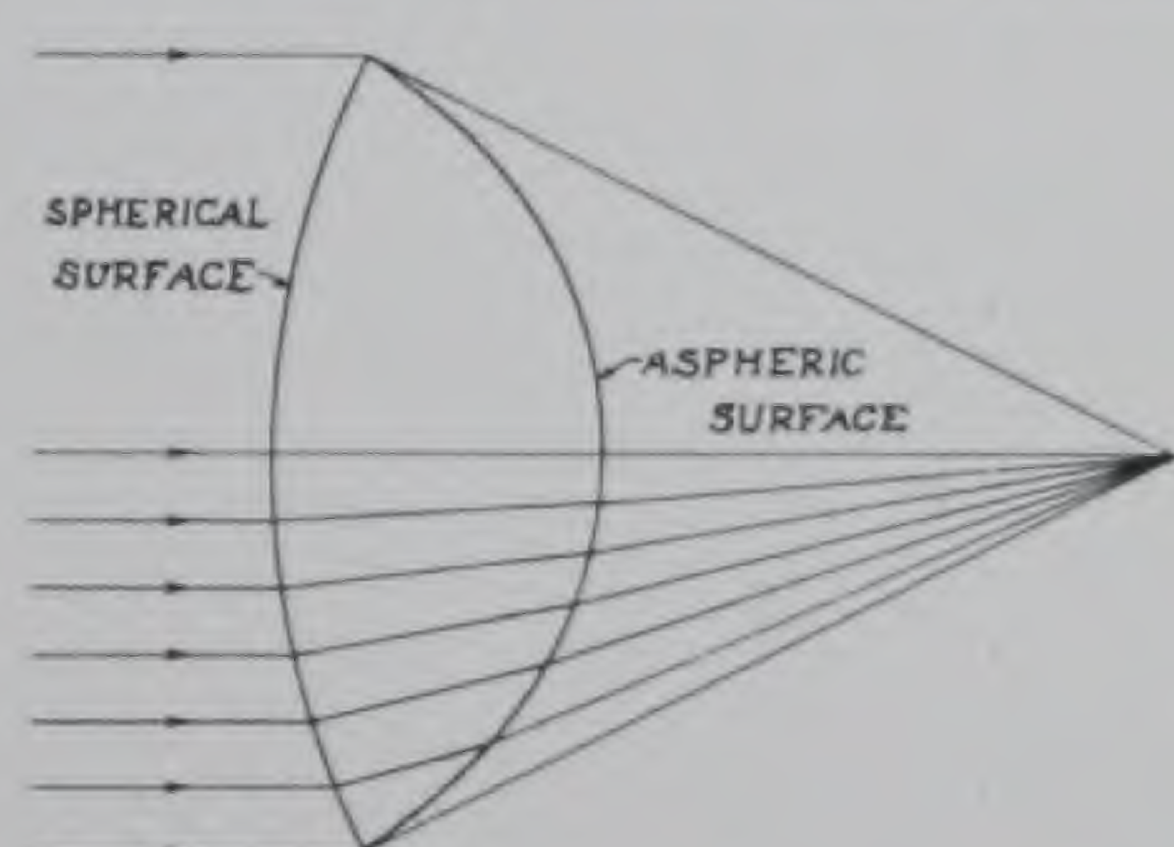


Fig. 23—Spherical aberration may be eliminated even in thick lenses by making one surface aspheric.

Aspheric Condenser

The aspheric condenser is recommended for use with MAZDA lamps. A condenser designed for use with the equipment illustrated on page 44 is shown complete with its mounting in Fig. 24. It consists of two elements, each with one surface ground aspheric. The diameter of the large lens is $5\frac{1}{2}$ inches and the angle of light intercepted is approximately 100 degrees as compared with 55-62 degrees for the plano-convex condenser and 78-80 degrees for the prismatic type. Increases of screen illumination of from 25 to 50 per cent over the prismatic and plano-convex condensers are obtainable; the greater increase occurs with the objective lenses of shorter focal length. Used in conjunction with a No. 2 or large size projection lens the aspheric condenser insures a maximum amount of uniformly distributed light on the screen.

Fig. 24—Aspheric condensing lens with mounting.

The source-condenser distance of this condenser is $1\frac{7}{8}$ inches for maximum screen illumination. This distance is correct for both the No. 1 and No. 2 projection lenses of any of the more common focal lengths. When this distance is used, a noticeable non-uniformity of screen illumination occurs without the mirror, but with the mirror in place satisfactory uniformity is obtained. The condenser-aperture distance is $6\frac{1}{2}$ inches.

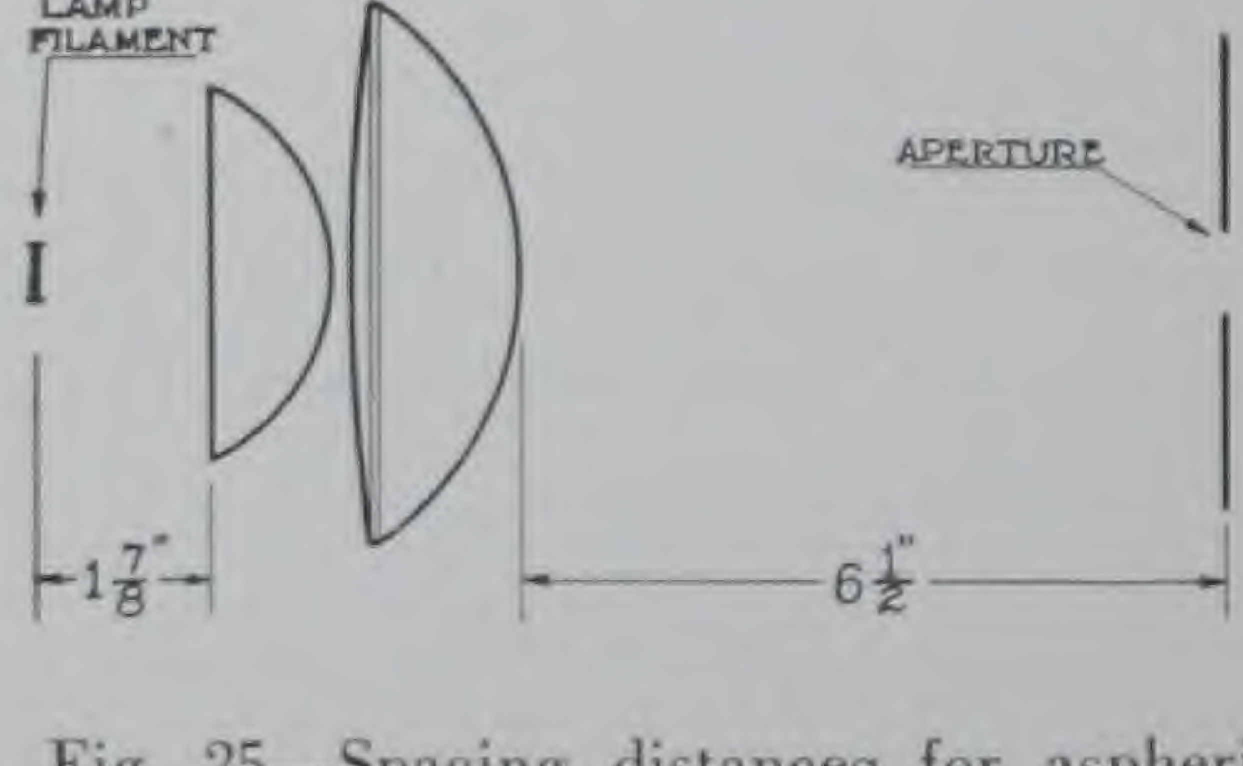


Fig. 25—Spacing distances for aspheric condenser for maximum screen illumination.

The aspheric condenser as designed for motion picture projection is ordinarily not suitable for stereopticon projection because the beam of light issuing from the condenser is of so great a diameter at the position of the stereopticon objective that very little light is received, and hence the screen illumination is poor.

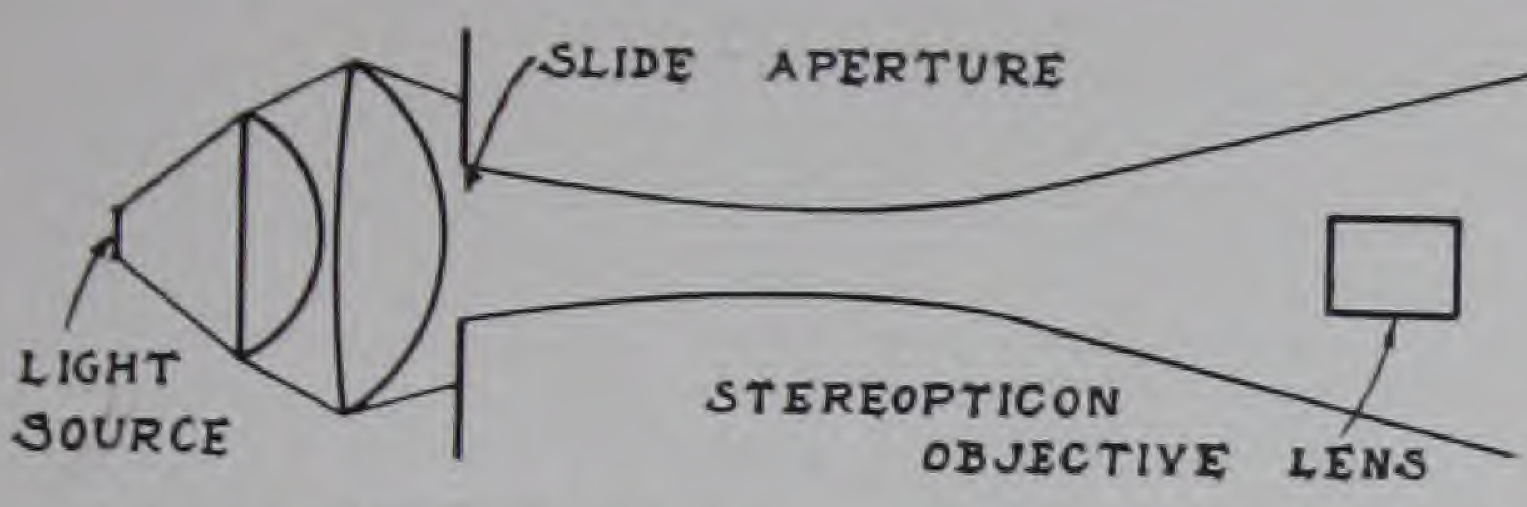


Fig. 26—With the aspheric condenser a stereopticon objective lens receives very little light.

Prismatic Condenser

As designed for theater motion picture projection the prismatic condenser has a diameter of $4\frac{7}{16}$ inches and intercepts light from the source through a plane angle of 78 to 80 degrees. It is designed for spacings of $2\frac{1}{2}$ inches between the source and condenser and $6\frac{1}{2}$ inches between the aperture and condenser, as shown in Fig. 22. Either lower screen illumination or less even light distribution results when this source-condenser distance is changed; the condenser-aperture spacing may, however, be varied one-half inch either way from the recommended distance without seriously impairing the results. Moreover, the required spacing need not be altered for different throws or size of picture. An advantage of the prismatic condenser as compared to the double plano-convex condenser is that slight displacement of the mirrored reflector does not cause an objectionable non-uniformity of screen illumination. The spacings are comparatively short, permitting compact design of the projector.

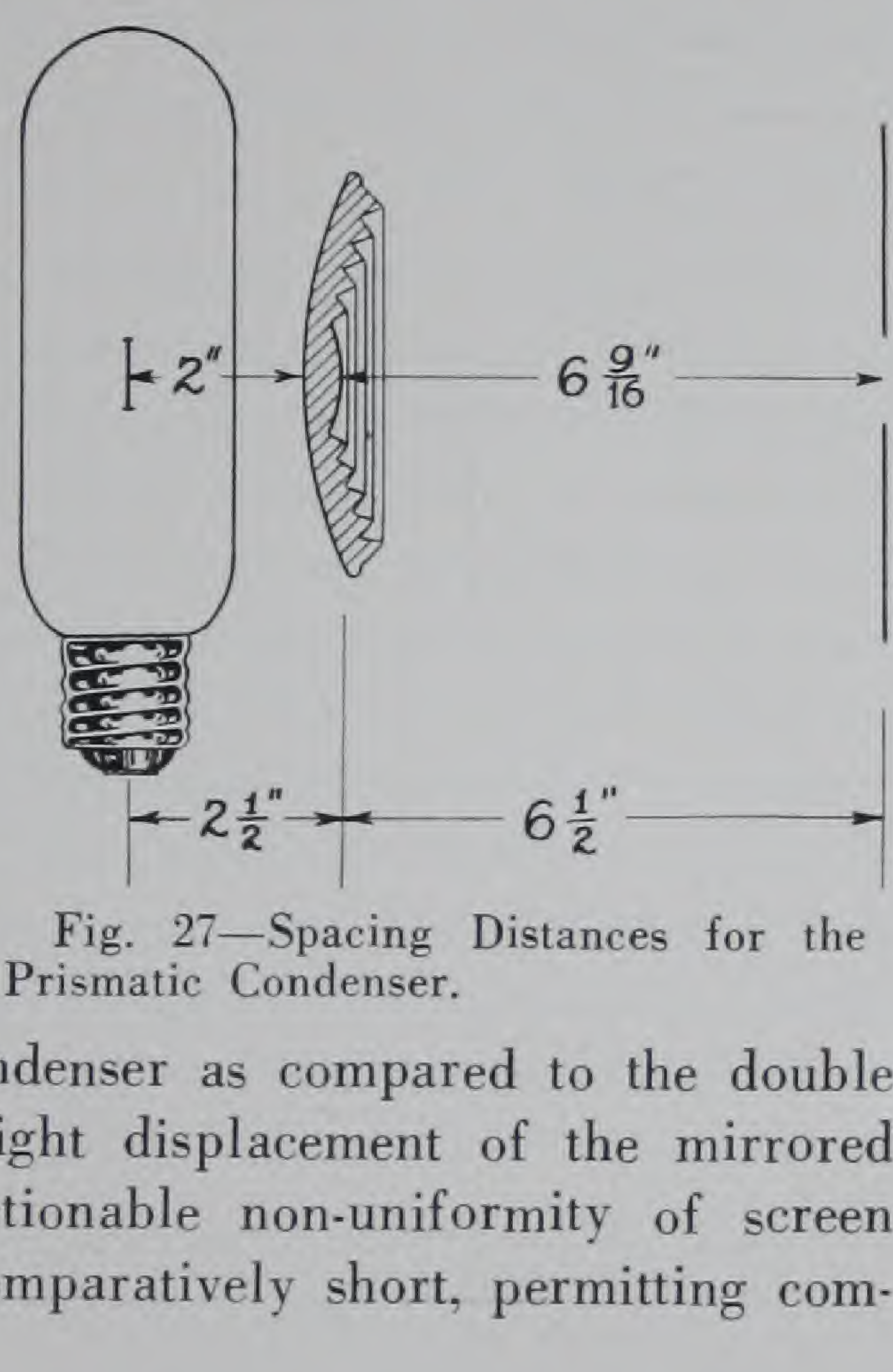


Fig. 27—Spacing Distances for the Prismatic Condenser.

A limitation of the prismatic condenser is that it is not suitable for slide projection since the risers of the prisms deflect the light so much that dark rings appear in the beam near the condenser where the slide would have to be placed to be covered by the beam, although these dark rings are filled in by the crossing of the rays farther out in the beam. For this service either a separate projection lantern must be used, which is the best practice, or condensing lenses suitable for slide projection must be provided in addition to the prismatic condenser.

Plano-Convex Condenser Combination

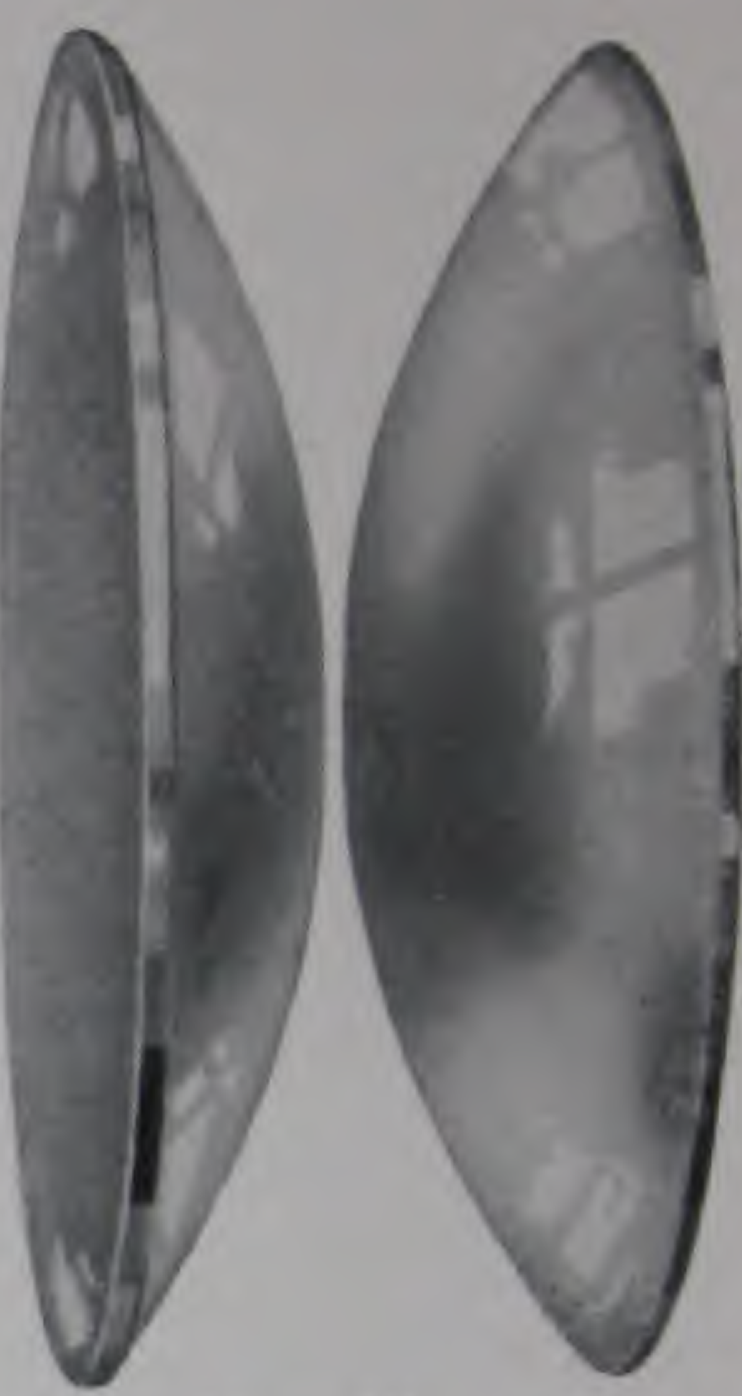


Fig. 28 — Plano-Convex condensing lens combination.

The beam of light from two plano-convex lenses is very uniform near the lens and this combination is therefore suitable for slide projection. Where it is used both for this purpose and the projection of the film, the slide holder is often fixed in front of the condensers, where it intercepts 15 per cent or more of the light which would otherwise pass through the film aperture. To avoid this unnecessary loss provision should be made for raising or lowering the slide holder away from the condensers, or moving it to one side during the projection of motion picture film.

The plano-convex condenser produces a well defined image of the lamp filament slightly beyond the smallest cross section of the beam, and there is a resultant unevenness of illumination at the narrowest part, where the aperture must be placed for best efficiency. Its success in motion picture projection is therefore dependent on the extent to which the source can be made uniform by filling in the spaces between the coils with coil images from the mirrored reflector. If the reflector is carefully set by precision methods applicable in laboratory rather than in theater practice, and certain source-condenser and condenser-aperture spacings are employed, it is possible to obtain with plano-convex condensers screen illumination values as high as those obtained with the prismatic condenser, with a tolerable uniformity of screen illumination.

Because compactness is so important in portable equipments, they require an optical system with its elements spaced closely. Hence the Fresnel, or prismatic condensers are often used. There has recently been developed a so-called three-quarters size aspheric condenser for equipments using 35-mm. film. The diameter and spacing distances are but three-fourths those of the standard size, and it offers practically the same screen illumination results as does the larger size, since, while the diameter is reduced, the light source is moved correspondingly closer, hence the angle of light picked up is unchanged.

The small projectors employing 16-mm. standard film may have even more compact optical systems without further sacrifice of illumina-

TABLE II
CONDENSING LENSES FOR MOTION PICTURE AND STEREOPTICON PROJECTORS

Service	Aperture	Condenser	Diameter (Inches)	Source-Condenser Spacing (Inches)	Condenser-Aperture Spacing (Inches)	Lamps
FOR MOTION PICTURE PROJECTION						
Theater	35 mm.	Aspheric	5½, 3⅞	1⅞	6½	900-watt, 28–32-volt
Semi-Portable and Portable	35 mm.	Aspheric Prismatic	3 13/16, 2 29/32 4 7/16	1 13/32 2½	4⅞ 6½	1000-watt, 115-volt 900-watt, 28–32-volt 600-watt, 28–32-volt 500-watt, 115-volt
Portable	35 mm.	Prismatic	3	1 9/16 (40 mm.)	3 15/16 (100 mm.)	500-watt, 115-volt
Portable	16 mm.	Aspheric	1 11/16	⅞	2¼	200-watt, 50-volt 200-watt, 115-volt
Portable	16 mm.	Triple Meniscus Plano-Convex or Double-Plano Convex	1¼	¾	1½	200-watt, 50-volt 200-watt, 115-volt 100-watt, 115-volt
FOR STILL PROJECTION						
Stereopticon	Standard Glass Slide	Double Plano Convex (6½ & 7½ inches focal length)	4½	3¾–4	½-⅝	900-watt, 28–32 volt 600-watt, 28–32 volt 1000-watt, 115-volt 500-watt, 115-volt
Film Slide	35 mm.	Double or Triple Plano Convex	1⅜–1 13/16	⅝–1⅜	⅜–2	200-watt, 115-volt 50-watt, 115-volt

tion other than that caused by the smaller aperture. The 16-mm. aperture has less than one-fifth the area of the 35-mm. aperture, hence large diameter condensing systems could not be used to advantage with the short spacing distances that must ordinarily be employed. The lamp filament is placed in a small diameter tubular bulb, ($1\frac{1}{4}$ inches in diameter in the case of the 200-watt lamp) permitting the light source to be placed close to the condenser. The condenser is designed with a short back focus and the solid angle of light intercepted is large compared to its diameter.

A smaller diameter aspheric condensing system has been designed for use in the projectors employing 16-mm. film. While the diameter is slightly larger, requiring somewhat greater spacing distances than the double plano-convex systems now commonly employed, this is more than compensated for by the 40-50 per cent increased illumination possible.

Table II shows types of condensing lenses for various equipments.

Aperture

The standard 35-mm. aperture is a rectangular opening 0.6795 inches high and 0.906 inches wide; the standard 16-mm. aperture is 0.28 inches high by 0.38 inches wide. The aperture plate across which the film moves must, for best efficiency, be located where as much as

possible of the converging beam from the condensing lens will pass through the opening and at the same time be uniformly distributed over this area. In practice a light beam larger in diameter than the diagonal of the aperture opening must be used since the light near the edge of the beam is of somewhat lower intensity and shows color due to chromatic aberration from the condensing lens, and this part, constituting from 40 to 65 per cent, must therefore be intercepted. If the aperture plate were located at position *a* of Fig. 29 an unnecessarily large amount of the light would be wasted; if placed in position *b*, the unevenness of distribution in the beam would become noticeable. In position *c* the aperture is correctly placed for the condensing lens shown; the light passing through it is uniform throughout the open area; only enough is intercepted to leave the projected beam practically uniform in cross section.

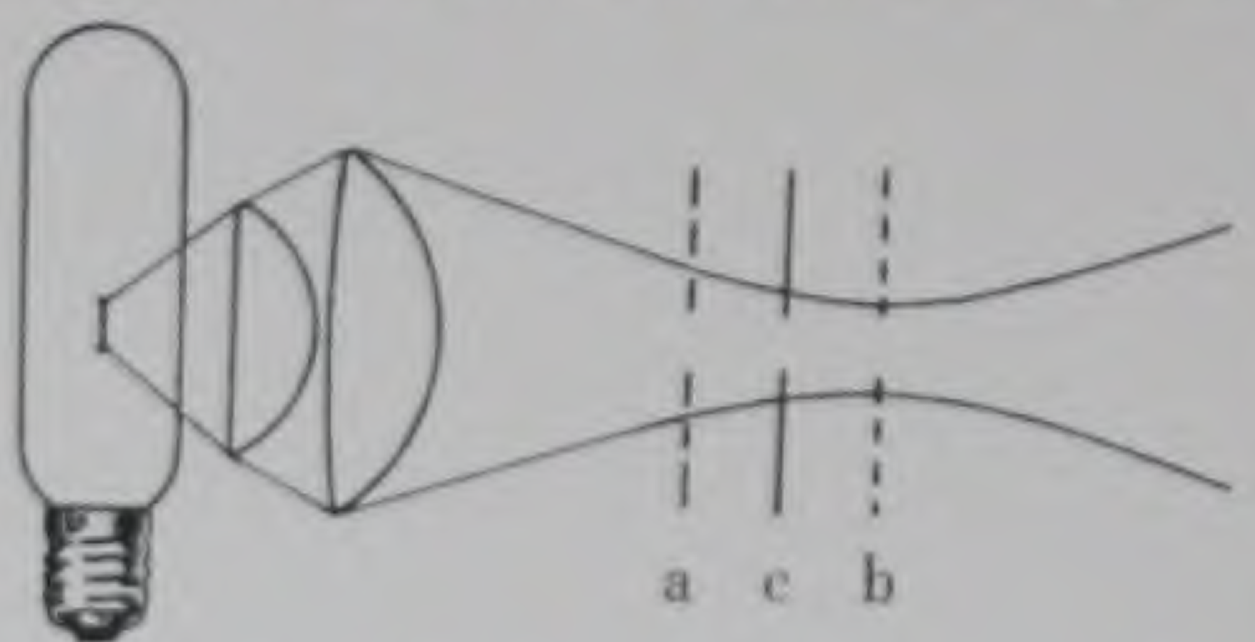


Fig. 29—Placing the Aperture—At position *a* considerable light is wasted; at *b* the beam is not uniform; position *c* is the correct one for the aspheric condenser.

With aspheric or prismatic condensers, which direct light to the film at wide angles, some light may be intercepted by the cooling plates located in front of the aperture. The openings in the plates should be enlarged until they do not interfere with the light coming from the outer zones of the condenser.

Projection Objective Lens

From Fig. 9 it will be seen that the projection lens consists of three elements, one of which is a cemented doublet. By combining suitable optical glasses in elements of proper thickness, surface curvature, and spacing, the units can be given the following characteristics:

1. Freedom from spherical aberration, providing good definition;

2. Flatness of field, which produces equally sharp images over the entire screen picture;

3. Freedom from chromatic aberration, eliminating colored fringes on the screen image;

4. Large diameter and free aperture, giving high screen illumination.

The focal length of the objective lens determines the picture size for a given projection distance. The shorter its focal length, the

greater its magnification and hence the larger the picture. For a given lens the picture size increases proportionately with the projection distance. With the width of the picture selected, the focal length of the required objective lens is given with sufficient accuracy for practically all purposes by the approximate formula:*

$$\text{Equivalent focal length (in.)} = \frac{\text{Throw (ft.)} \times 0.906^{**}}{\text{Picture Width (ft.)}}$$

The projection distance is measured from the center of the objective lens to the screen.

For a given distance, increase in the picture area decreases the average screen intensity but not proportionately, since a larger amount of light is transmitted by the projection lenses of shorter focal length used for the larger picture.

Maximum and minimum limits of desirable picture size are determined by the angle which the picture subtends at the eyes of those in the front seats and those farthest away from the screen. Observations indicate that under usual conditions the picture appears too small if its width subtends an angle of less than about nine degrees, and, on the other hand, it cannot be viewed with comfort by those at the front of the house if at their eyes it subtends an angle of more than about 45 degrees.

Objective lenses for theater use are obtainable in two sizes, the "quarter" size or No. 1 lens of about $1\frac{1}{2}$-inches free aperture, and the "half size" or No. 2 lens of about $2\frac{1}{2}$-inches free aperture. As is shown in Fig. 30, the beam diverges rapidly after passing through the aperture, and to obtain maximum screen illumination the lens of larger diameter should be used. The curves of Fig. 31 show the relative amounts of light projected to the screen with objectives of the two sizes and the aspheric condenser. In general, twice as much light is projected with the larger lens. High grade No. 2 projection lenses should be used for projection with MAZDA lamps. They are at present obtainable for all focal lengths from $4\frac{1}{2}$ inches upward. High grade objectives are also available in the No. 1 sizes for the shorter focal lengths.

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*The exact formulae are:

$$EF = \frac{12T}{1+13.25W} \qquad T = \frac{EF}{12}\,(1+13.25W) \qquad W = \frac{0.906T}{EF} - 0.0755$$

Where EF = Equivalent Focal Length (inches) T = Throw (feet) W = Width of picture (feet).

**Substitute 0.38 for 0.906 in approximate formula with 16-mm. equipment.

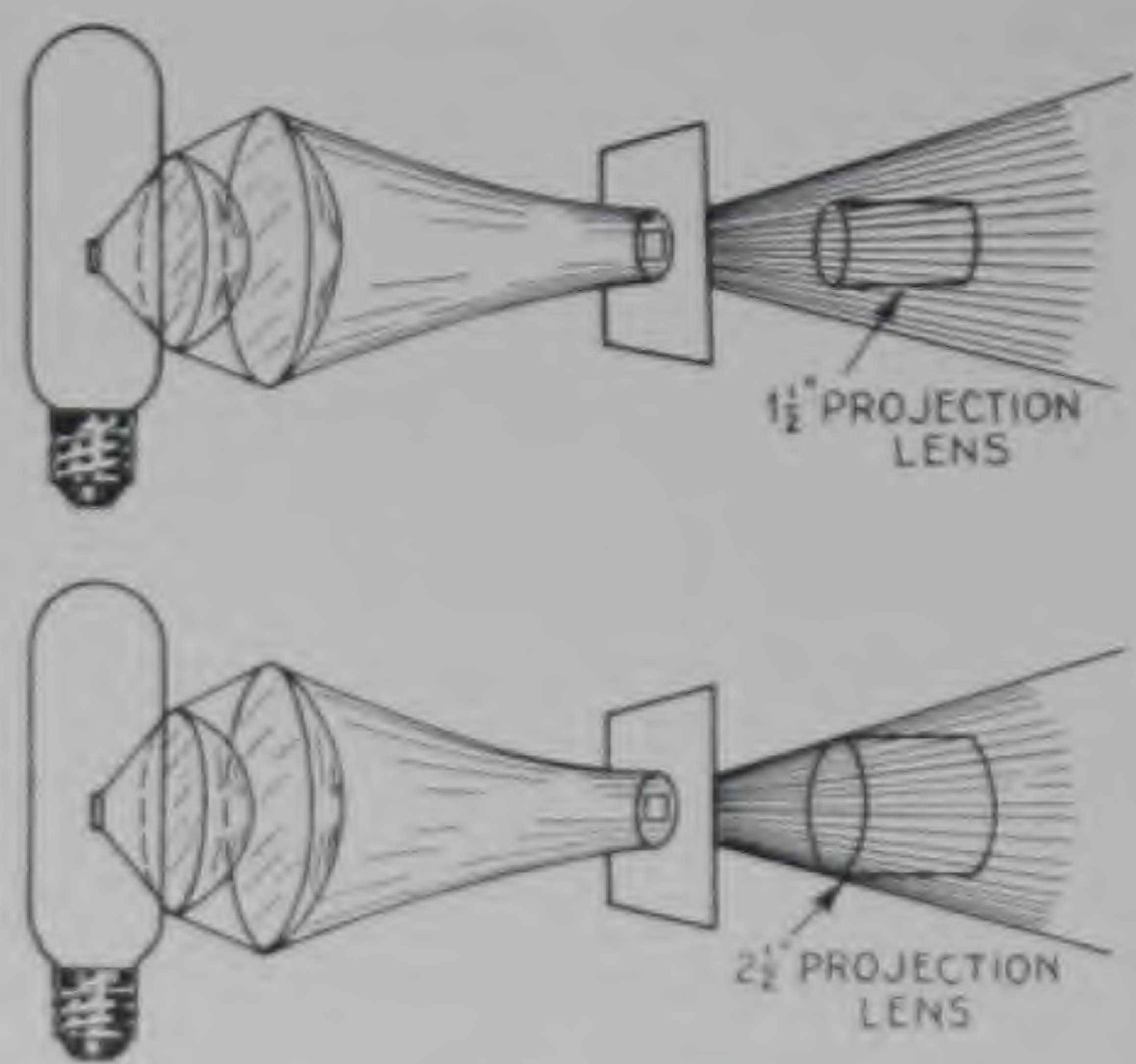

Fig. 30

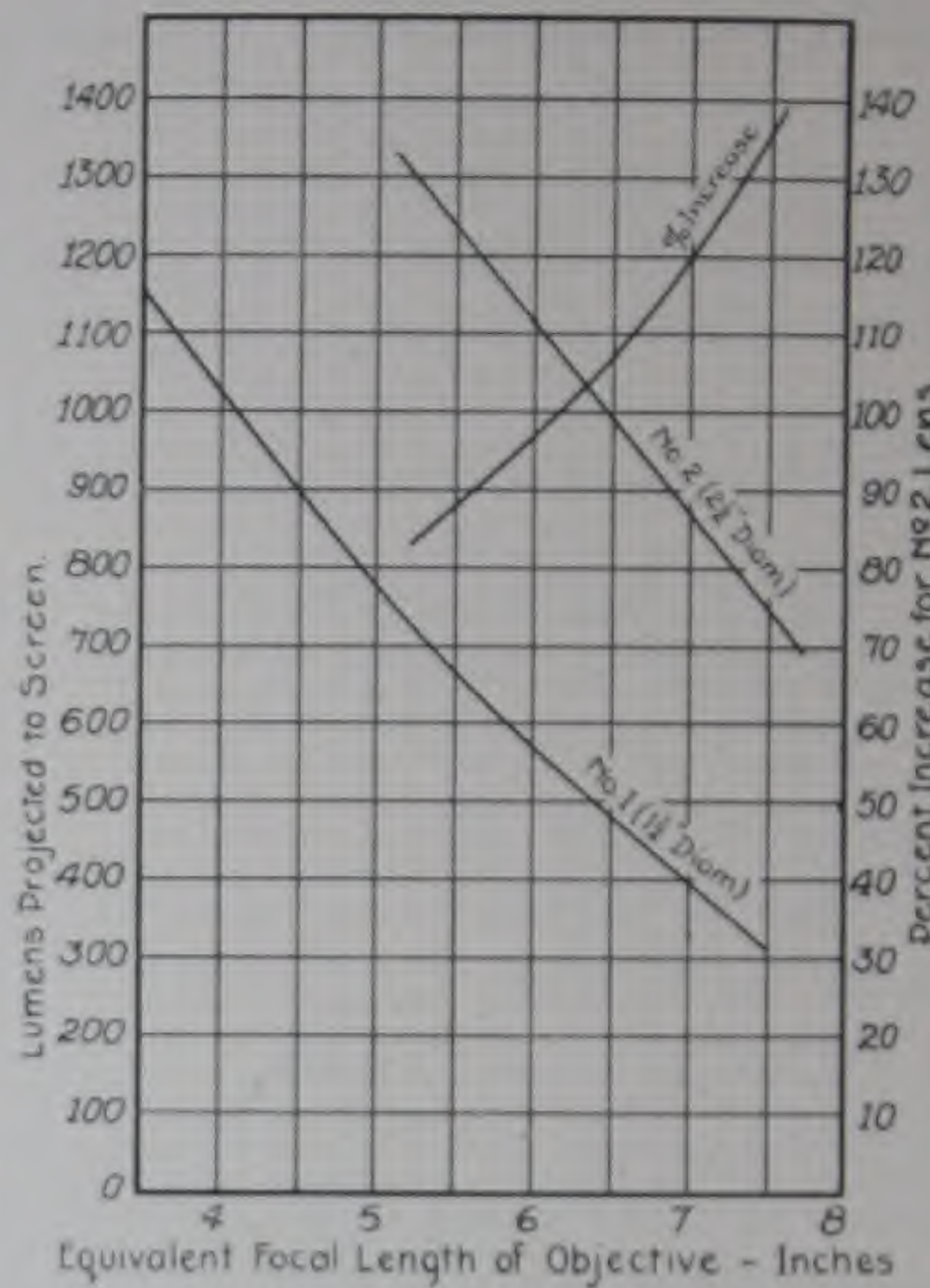

Fig. 31

The cross-section of the beam at the position of the objective lens (Fig. 30) is so large that the No. 2 objective lens utilizes twice as much light as does the No. 1 lens. The curves of Fig. 31 show the light flux projected to the screen when the 900-watt, 30-ampere MAZDA lamp and the aspheric condenser are used with the No. 1 and No. 2 projection lenses of various focal lengths. Beam unobstructed by rotary shutter, film or cooling plate.

Because of its lower price, the No. 0 size lens is sometimes used in portable equipments. The screen illumination obtained with this lens is about 75 per cent of that obtained with the No. 1 lens, and the consequent saving in lens cost will seldom compensate for this loss of light.

Objective lenses of shorter focal length, ordinarily ranging from 1 to 3 inches, are used with 16-mm. film projectors to obtain sufficient magnification of the smaller film for the short projection distances ordinarily employed. Their diameter may therefore be somewhat restricted without serious loss of light.

Objective lenses of 10 to 24 inches focal length are ordinarily used with the standard glass slide projectors since lesser magnification is needed for a given picture size. Here again the larger diameter lenses should be used for maximum illumination.

The tables on pages 45 to 47 show the approximate picture dimensions for objective lenses of various focal lengths at different distances from the screen for 16-mm. and 35-mm. motion picture film, and standard glass slide projectors.

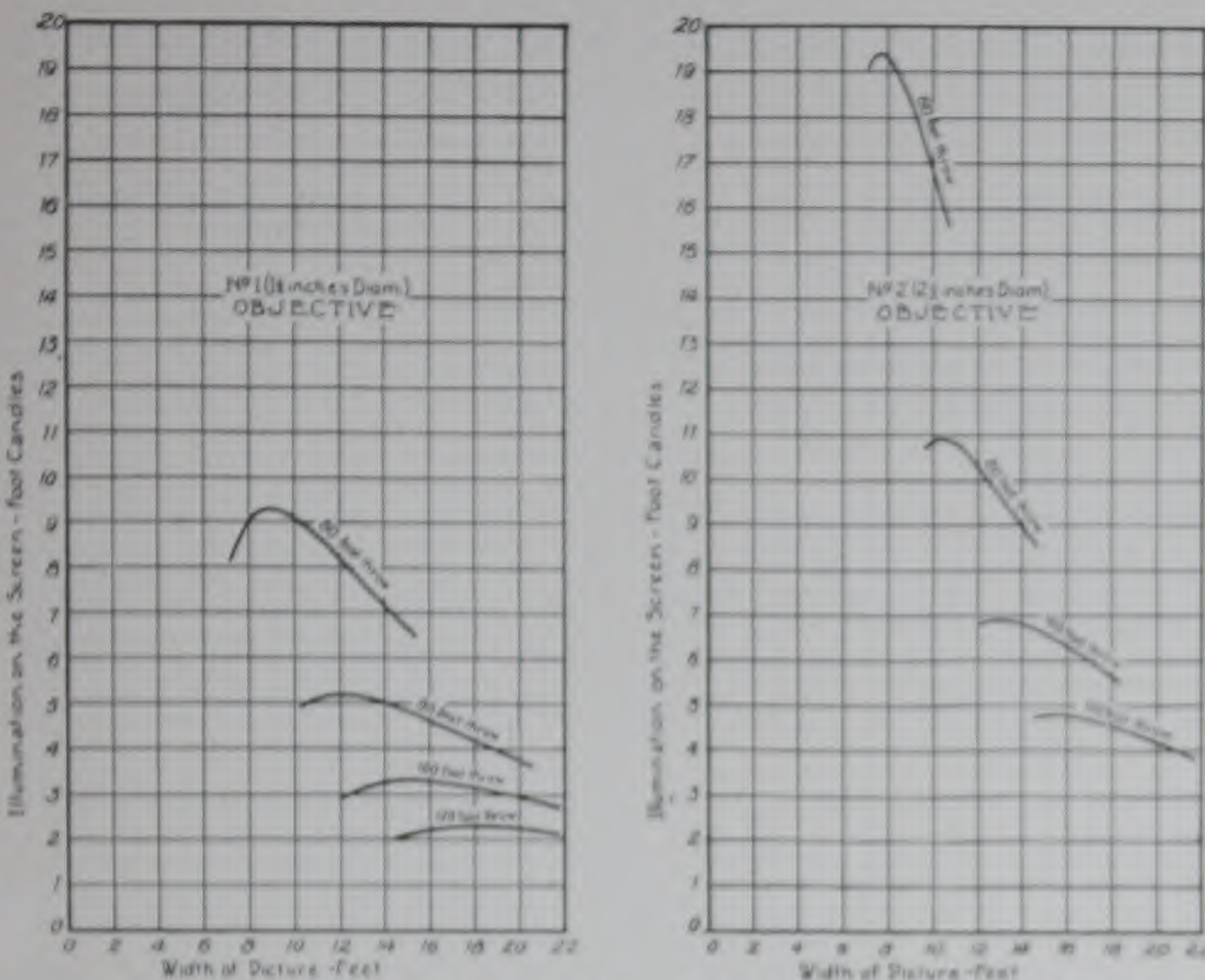

Fig. 32—Variation of screen illumination with picture size for 900-watt MAZDA Lamp and aspheric condenser. Beam unobstructed by shutter, film, or cooling plate.

Rotary Shutter

Figure 33 shows a typical rotary shutter which is placed in the light beam beyond the aperture and adjusted so as to cut off the light from the screen during the period that the film is in motion. The blade is made of such a width that the film starts to move before the light beam is entirely cut off and the blade also starts to uncover the beam before the film is stopped. The periods during which the stationary film is being covered and uncovered are thus reduced to a

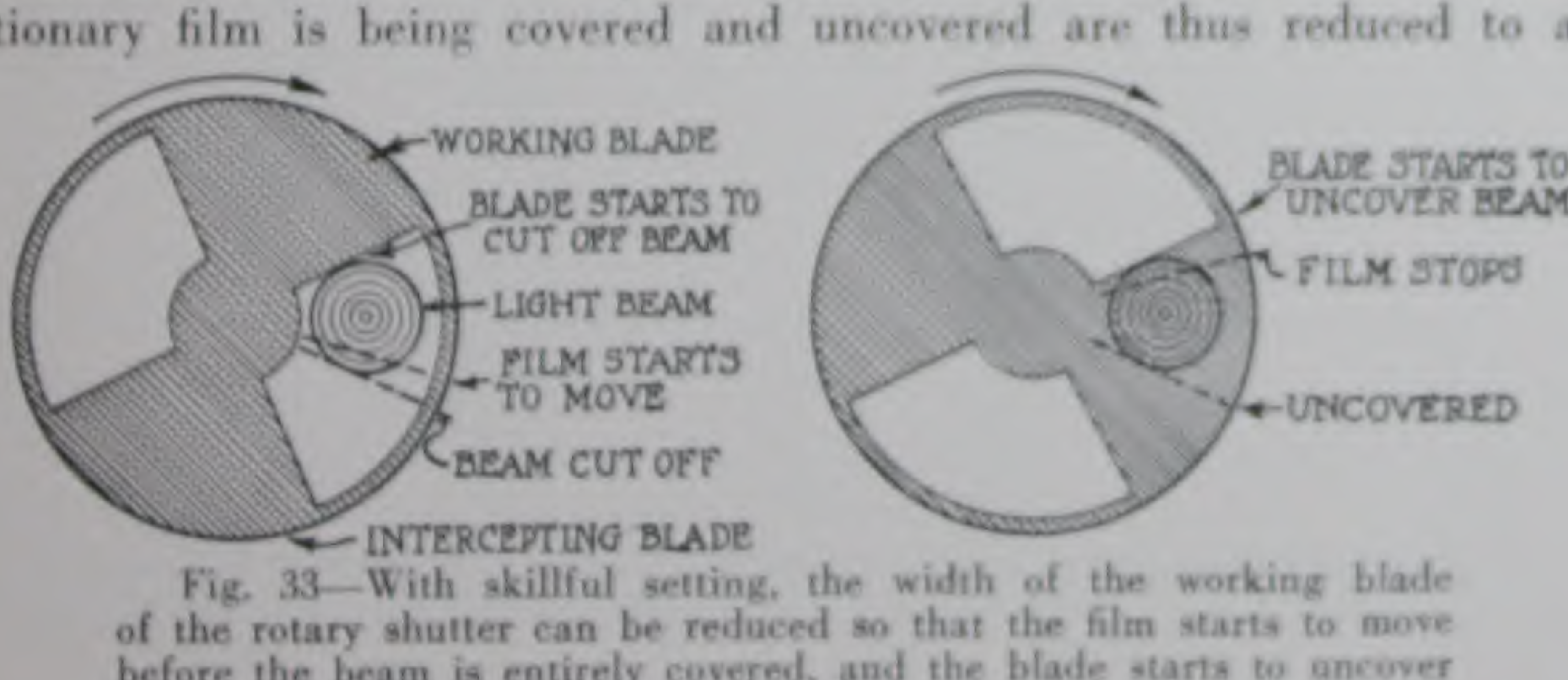

Fig. 33—With skillful setting, the width of the working blade of the rotary shutter can be reduced so that the film starts to move before the beam is entirely covered, and the blade starts to uncover before the film movement has stopped.

minimum; the small amount of light reaching the screen during the short period of exposed film movement is not noticed.

Interruption of the light just 20 times per second would result in pronounced flicker, therefore one or two blades are provided in addition to the working or "travel" blade that cuts off the light during the film movement. These intercepting or "flicker" blades can by skillful design be made narrower than the working blade and thus the loss of light may be reduced. The number of blades required depends on the brightness of the screen. At ordinary intensities of screen illumination a two-blade shutter interrupting the light 40 times per second at normal projection speed eliminates flicker; but with a very bright screen a three-blade shutter interrupting the light 60 times per second is required. The two-blade shutter can in most cases be employed with MAZDA lamps.

Since the angular width of the working blade is determined by the ratio of time of film movement to the stationary period, the shutter transmission varies with the intermittent ratio as well as with the size of the objective lens, or the width of the light beam. For best efficiency the shutter should be placed where the beam diameter is smallest. With the condenser spacings used in MAZDA lamp systems, the light beam emerging from the objective lens is smallest in diameter at the lens, so that the narrowest blades for an outside shutter can be used when the shutter is placed as close as practicable to the lens holder.

The rotary shutters ordinarily employed have a transmission of about 50 to 55 per cent for the two-blade type and from 40 to 45 per cent for the three-blade type. Successful designs of the former are in use having a transmission of 60 per cent for a No. 2 lens. Skillful narrowing of the blades and their perforation with small holes are methods employed to obtain the higher transmission values. If carried too far with the working blade a "travel" ghost is noticeable on the film titles. Whatever additional light is obtained by such modification of the intercepting blade without having flicker appear on the screen is probably a clear gain, but any light received on the screen through the moving film is a detriment rather than an advantage.

It should be noted that wherever data are given in this bulletin showing the transmission of light through various optical systems they apply for the beam unobstructed by a shutter.

Screen

The last step in the projection of a satisfactory picture lies in selection of a proper screen. If a type is chosen whose light distribution does not fit the particular theater or room, inefficient and unsatisfactory projection results.

The screen should have a high reflection factor, and its characteristics should be such that the picture appears nearly equally bright from all seats. There are three general types of screens having quite different characteristics, as shown in Fig. 34. These satisfactorily meet all requirements.

A white mat (diffusing) surface reflects light about equally in all directions. Consequently a person sitting at a wide angle with respect to the screen receives practically as much light as one sitting directly in front. Such a screen therefore is best adapted to wide houses where a fair proportion of the seats are at angles of 30 degrees or more with a normal to the center of the screen.

A smooth metallized surface redirects the light into a relatively narrow beam of high intensity, consequently in narrow and medium width houses it serves to increase the picture brightness because it directs toward the audience a larger portion of the light which otherwise would be wasted on the walls.

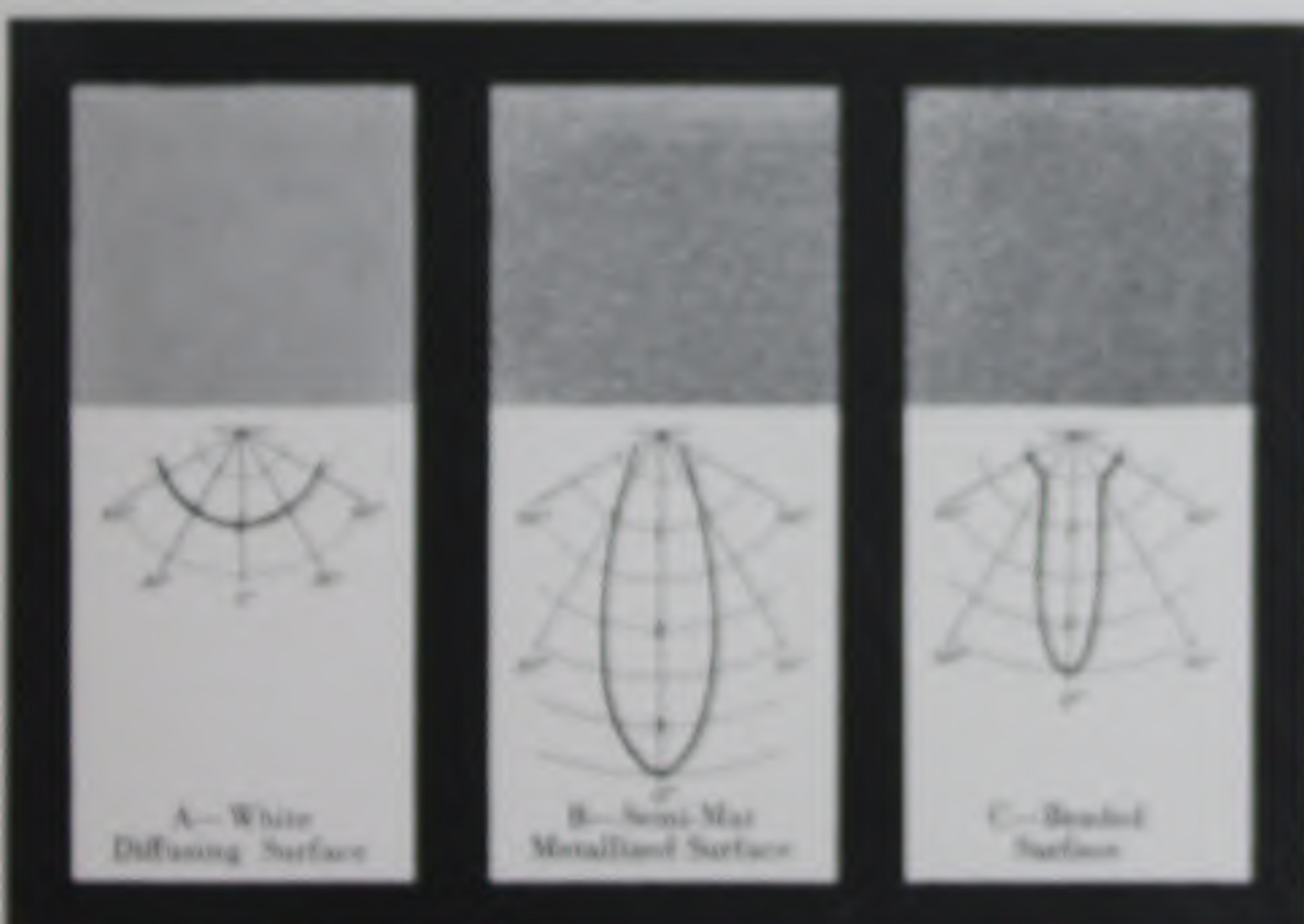

Fig. 34—Three typical screen surfaces and brightness distributions—equal illumination incident normal to the surfaces.

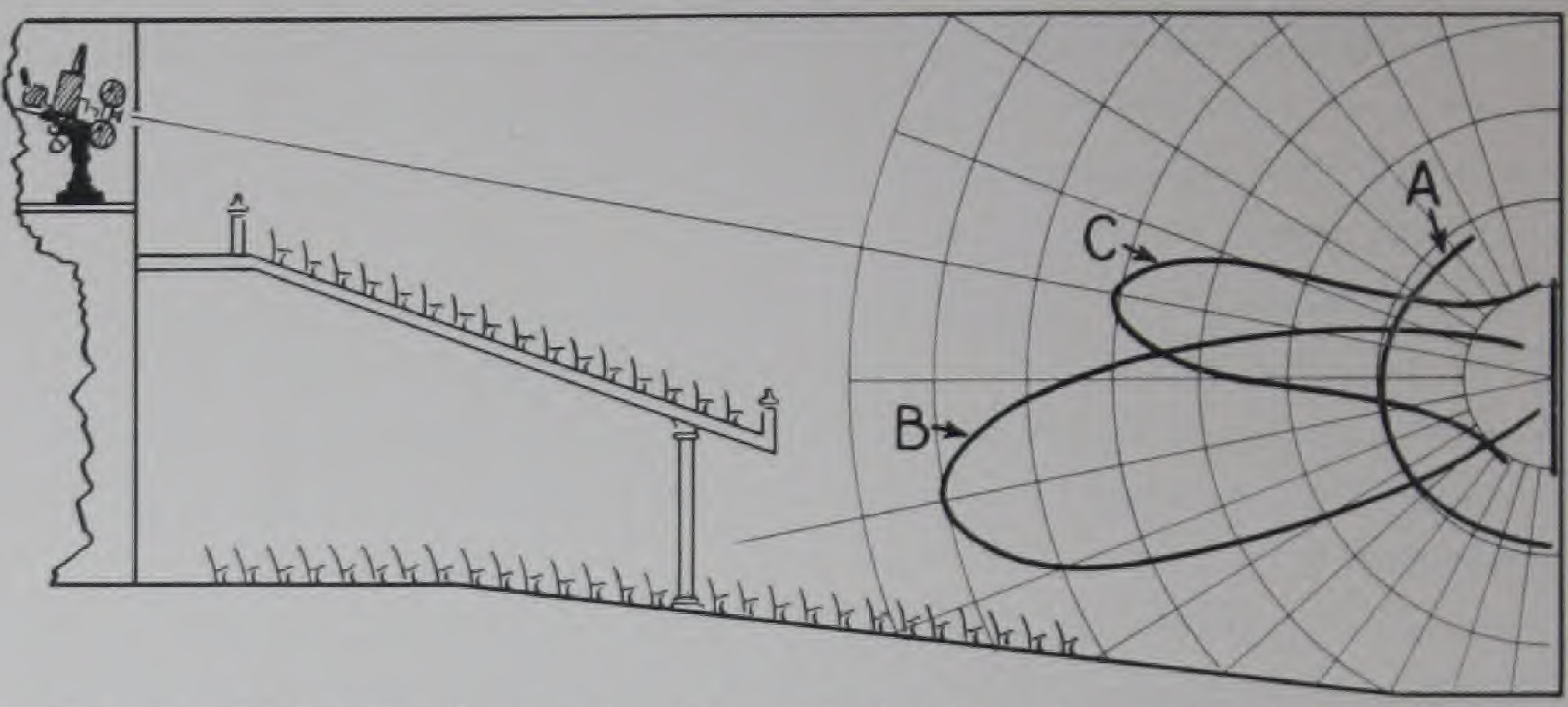

Fig. 35—Light distribution in the vertical plane from the three types of screen surfaces illustrated in Fig. 34.

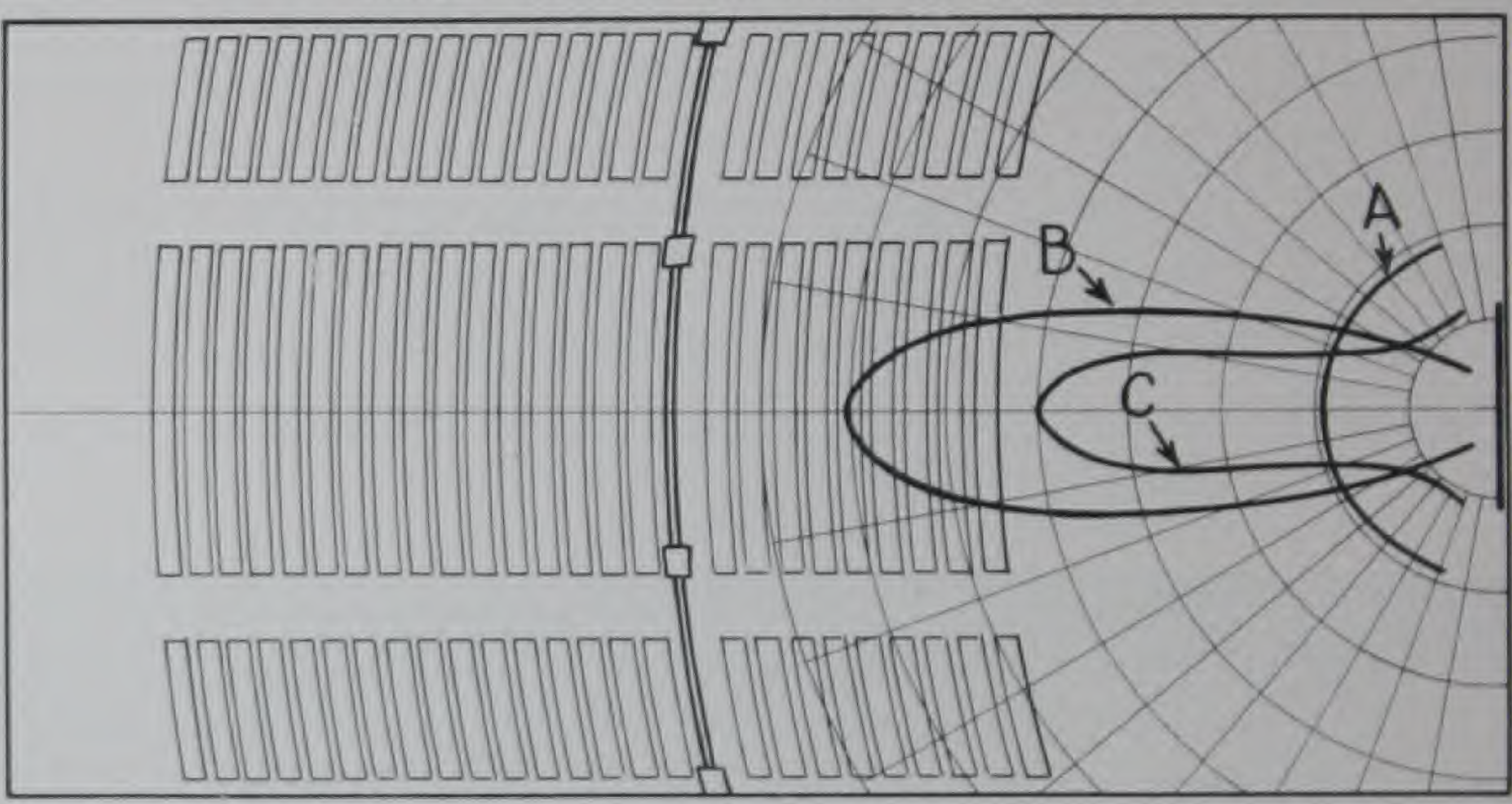

Fig. 36—Light distribution in the horizontal plane from the three types of screen surfaces shown in Fig. 34.

The beaded screen combines characteristics of the other two types. The screen surface diffuses some of the light out at the wider angles, and the remainder is directed into a narrower angle from the surfaces of the beads. The beaded screen, therefore, finds its best application in houses of medium width and those in which side seats at wider angles are used only part of the time.

The way to determine which type of screen will give most satisfaction to the greatest number of the audience is to superimpose the respective curves of brightness distribution (Figs. 35 and 36) on the plan and elevation of the house. A good general criterion for the selection of the proper screen surface, which has been advocated, is that the maximum brightness, directed by the screen to the center seats, should not exceed four times that directed to the side seats at the front.

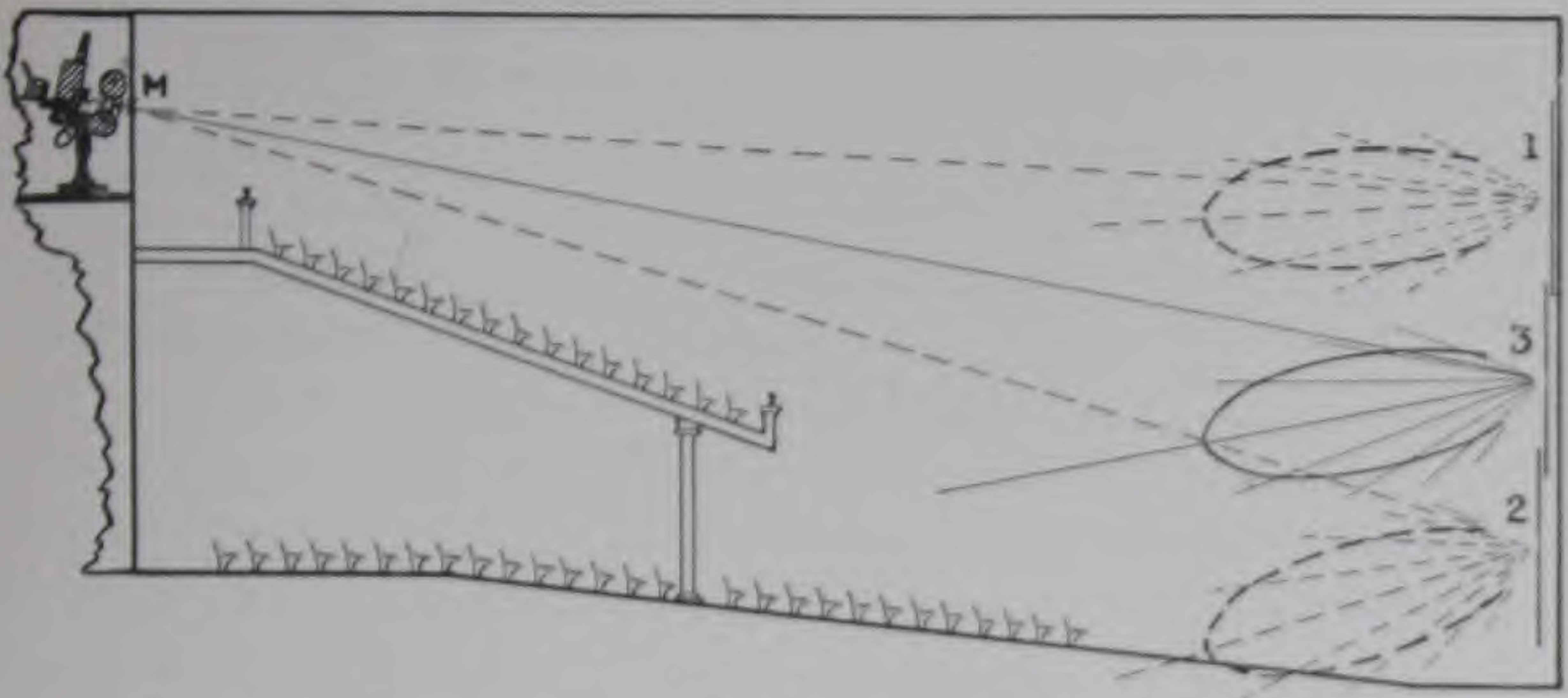

Fig. 37—Apparent screen brightness as affected by height of mounting: Position 1 favors the high balcony seats; position 2 wastes most of the light; position 3 is probably most effective for this house.

In the foregoing, reference has been made only to the light distribution in the horizontal plane, but since the seats are at various elevations the brightness distribution in the vertical plane must also be considered. This is especially important in view of the fact that the three types of screen surfaces act differently in reflecting the light received at an angle with a normal to the surface. From the metallic surface screens, for example, the reflection is to a considerable extent specular, as from a mirror; that is, the general direction of the reflected beam makes an angle with the normal equal to the angle of incidence, as in Fig. 35, B.

A metallic surface screen in the theater shown in elevation in Fig. 37 would give an unsatisfactory distribution of light if placed in position *1*. Position *2* would favor the front seats at the expense of those in the rear and balcony, but position *3* would give a well balanced distribution of the light. Tilting the screen backward at the top assists in raising the angle of maximum brightness in case the screen cannot be mounted at the desired height. The comfort of the audience must also be considered in determining the best screen position; if it is too high, those near the front cannot be at ease in viewing the picture. The bead screen reflects a maximum brightness in the direction of the projector, as shown in Fig. 35, C, because the specular part of the reflection is largely from that part of the glass bead surfaces normal to the beam. Obviously this screen finds its best application in theaters where the seats are not far below the projected beam. The direction from which the incident light is received has little effect on the distribution from the diffusing screen, as shown by Fig. 35, A.

The screen brightness necessary to produce the best pictures varies with the reflecting characteristics and texture of the screen surface employed. The most satisfactory brightness appears to be materially lower with a diffusing type of screen than with those giving a pronounced directional distribution. This tends to make the results with the diffusing screen relatively better than would be indicated from the respective brightness values given in the above discussion. An additional factor to be taken into consideration is that a lower order of brightness suffices for the seats near the screen than for those farthest away. Although for a given light source the screen brightness decreases somewhat with the larger pictures, as may be seen from the illumination values of Fig. 32 there is a compensating factor in that the brightness required for good viewing decreases as the size is increased.

The same care should be taken in the selection of a screen for the school, church, or industrial auditorium as for the theater. Quality projection requires the choice of a suitable screen which fits the size and shape of the auditorium in which it is being used.

It is often necessary to employ one which may be rolled up in the interest of portability or compactness. In this event, a material should be selected which will not flake or crack within a reasonable period.

A relatively small amount of extraneous light striking the reflecting screen will reduce the contrasts of brightness values on the screen to the point of spoiling the picture. It is therefore necessary to darken the room when the reflecting screens are used. But in the school room, brokers' offices, etc., it is especially desirable that pictures be shown without darkening the room. The use of the so-called daylight or translucent screen between the projector and the audience makes good projection possible in moderately lighted rooms. The room light striking the face of the screen passes through, instead of being reflected back to the audience; thus the contrasts of the picture are not modified. The screen must, however, be shaded against extraneous light from the rear (projector) side, since this would pass through and reduce the brightness contrasts of the picture. Translucent screens obviate the necessity of special window shades, but they must be placed some distance from the wall to obtain a picture of sufficient size, and hence the seating capacity of the room is decreased.

A sheet or table cloth often answers the purpose of a screen in the home. While fairly good projection results may be so attained, this practice is ordinarily inconvenient. It is usually difficult to find a

suitable place for hanging such a screen and the position of the projector and audience is thereby limited. Small framed screens, made of the same materials that are used in the large auditoriums, are available for this service, and may be mounted on a telescoping tripod. Such a screen may be placed in any position convenient to the audience, and may be rolled up and kept with the projector.

Illumination of the Theater Auditorium

The illumination of the auditorium during the projection of the picture vitally affects the required screen brightness, and the selection and placing of the lighting equipment must therefore be treated as a phase of the projection problem. There must be sufficient light to create an agreeable atmosphere and to permit the theater patrons to find or leave their seats safely during the projection of pictures, yet the eye should encounter no very bright areas and the light directed to the screen from fixtures or vertical surfaces facing the stage should be kept at a minimum, in order that contrasts in the screen picture will not be materially affected. If but one per cent of the screen brightness is contributed from sources other than the projector, the screen illumination must be increased by 30 to 40 per cent in order to produce as satisfactory results as though no extraneous light reached the screen. The other surfaces at the front of the house should, however, receive some illumination so that excessive contrasts of brightness may be avoided. The theater exterior, lobby, and to a lesser extent the foyer are usually brilliantly lighted in order to appear cheerful and attractive. However, the eyes of the patrons are thereby adapted to this level and it requires time for their adjustment to the lower level desirable in the auditorium. By lighting the rear of the auditorium to a moderate intensity and gradually decreasing this to the front, the eyes are given an opportunity to adapt themselves as one passes down the aisle, and at the same time the illumination reaching the screen is kept at a minimum. The use of indirect lighting equipments, or units with deep reflectors, shades, or shields, and of auxiliary aisle lighting, obviates the interference with vision caused by bright surfaces near the field of view Frequently beams or other architectural features may be employed to prevent the direct light from reaching the stage and to shield the eyes of the audience. The brightly lighted music sheets of the orchestra may cause annoyance when in the line of vision, and they sometimes reflect a considerable amount of light to the screen. Judicious placing and masking of the music racks will frequently improve these conditions.

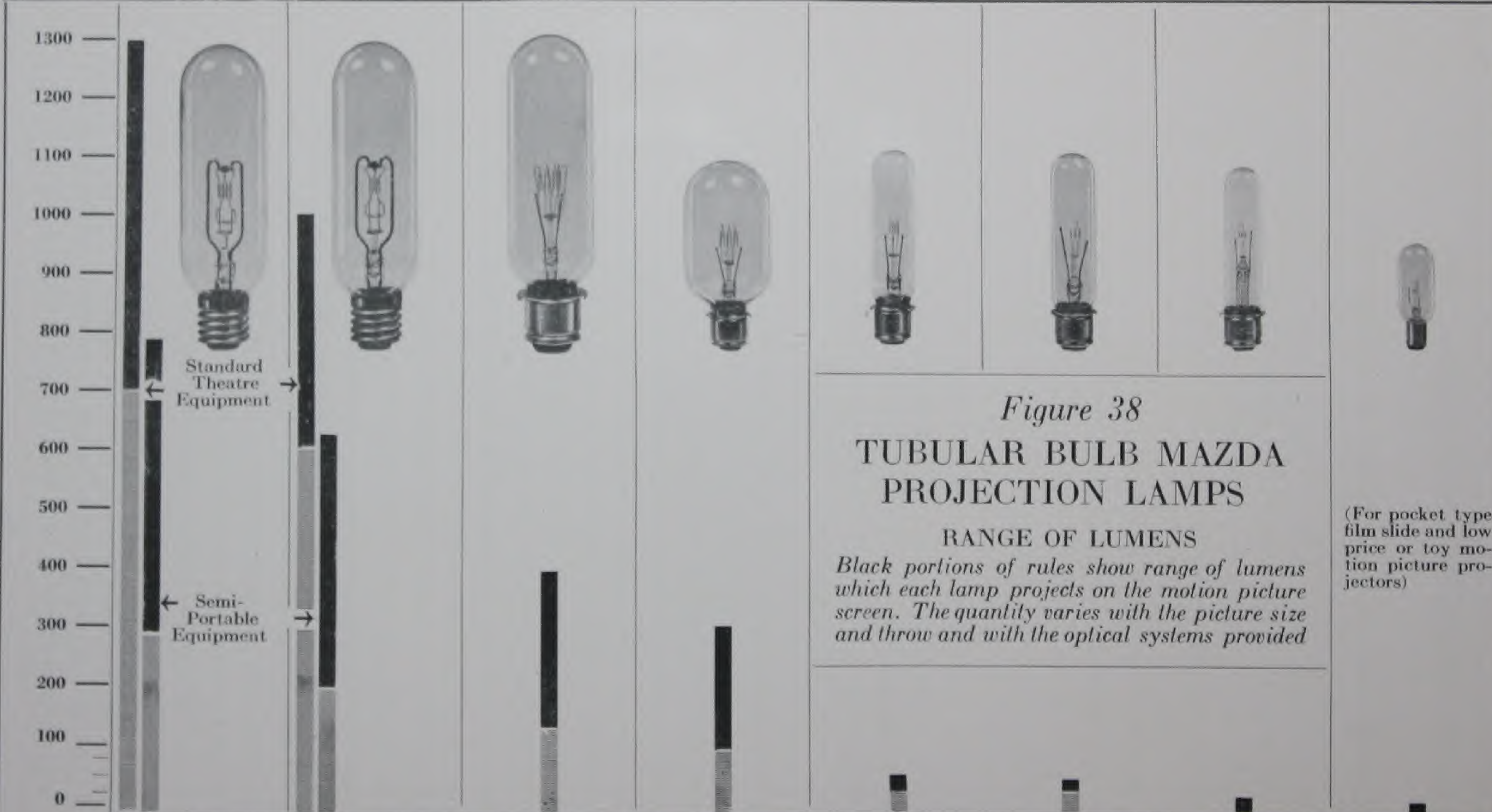

Figure 38

TUBULAR BULB MAZDA PROJECTION LAMPS

RANGE OF LUMENS

Black portions of rules show range of lumens which each lamp projects on the motion picture screen. The quantity varies with the picture size and throw and with the optical systems provided

900-watt 30-ampere T-20 Bulb Mogul Screw Base 4¾-inch Light Center Length 9½-inch Over-all Length 11.0 x 13.2 mm. Source	600-watt 20-ampere T-20 Bulb Mogul Screw Base 4¾-inch Light Center Length 9½-inch Over-all Length 9.3 x 10.9 mm. Source	1000-watt 115-volt T-20 Bulb Mogul Prefocus Base 3 7/16-inch Light Center Length 9⅜-inch Over-all Length 16.0 x 13.6 mm. Source	500-watt 115-volt T-20 Bulb Medium Prefocus Base 2 3/16-inch Light Center Length 5¾-inch Over-all Length 13.0 x 12.6 mm. Source	200-watt 50-volt T-10 Bulb Medium Prefocus Base 2 3/16-inch Light Center Length 5¾-inch Over-all Length 7.0 x 6.8 mm. Source	200-watt 115-volt T-10 Bulb Medium Prefocus Base 2 3/16-inch Light Center Length 5¾-inch Over-all Length 7.4 x 7.6 mm. Source	100-watt 115-volt T-8½ Bulb Medium Prefocus Base 2 3/16-inch Light Center Length 5¾-inch Over-all Length 5.8 x 4.9 mm. Source	50-watt 115-volt T-8 Bulb D. C. Bay. Cand. Base 1⅜-inch Light Center Length 3⅛-inch Over-all Length 5.0 x 5.0 mm. Source

All light source dimensions are approximate and subject to a tolerance of ± 10 per cent.

MAZDA LAMPS FOR PROJECTION SERVICE: THEIR CORRECT APPLICATION

To meet the needs of the various fields of motion picture and stereopticon projection, there has been developed a group of lamps especially adapted for these services, and known as Standard Schedule lamps. They are carried in stock by many dealers of stereopticon and motion picture equipment throughout the country and hence are quickly and easily obtainable. The advantage of designing equipments to function with these lamps rather than special types, is obvious.

The field of application for each lamp is indicated in a general way in Table I, page 2. The values of picture sizes and projection distances shown should not be taken as exact limits as these depend upon the optical efficiency of the projector, the width of the room or auditorium, and the type of screen. The complete standard line of projector and stereopticon lamps is shown in Fig. 38 together with the screen illumination values obtainable with well designed motion picture projectors.

The low voltage lamps have relatively short filaments as compared with lamps of the 115-volt group, and their greater filament concentration results in improved utilization of the light through the optical system, hence higher screen illumination. However, for many applications outside of the theater field, the concentration possible with filaments designed for operation on the standard 115-volt circuits proves sufficient, and the cost of auxiliary transformer or resistance equipment is thereby obviated.

A recent development in lamp design has made possible greater concentration of filaments made for use without voltage regulating equipment on 115-volt circuits. The ordinary coiled type of filament is coiled again, making a double-coiled, or what is known as the coiled-coil light source. This type of filament construction can at the present time be applied to advantage only to lamps of 200 watts rating and less, and it shows to advantage when applied to lower voltage lamps. However, it makes possible the achievement of good screen illumination results with standard circuit voltage lamps in the popular 16-mm. projectors, and may be used for other services requiring high concentration of 115-volt filaments.

The 16-mm. aperture places a lower limit upon the effective light source area than does the 35-mm. aperture, also limiting the lamp wattage which may be employed to advantage. At the present time, the 200-

PICTURE PROJECTION WITH MAZDA LAMPS

PICTURE PROJECTORS AND THE LAMPS THEY USE

Projector	Model	Manufacturer	MAZDA LAMP USED				
			Watts	Volts	Bulb	Filament	Base*
STANDARD THEATRE MOTION PICTURE PROJECTORS (35-mm. Film)							
Fulco	......	The Fulton Co.	900	28–32	T-20	C-13	Mog. Screw
Holmes	......	Holmes Projector Corp.	900	28–32	T-20	C-13	Mog. Screw
Motiograph	......	Enterprise Optical Co.	900	28–32	T-20	C-13	Mog. Screw
Powers	......	International Projector Corp.	900	28–32	T-20	C-13	Mog. Screw
Simplex	......	International Projector Corp.	900	28–32	T-20	C-13	Mog. Screw
Superior	......	Coxsackie Holding Corp.	900	28–32	T-20	C-13	Mog. Screw
SEMI-PORTABLE MOTION PICTURE PROJECTORS (35-mm. Film)							
Acme	SVE	International Projector Corp.	1000	115	T-20	C-13A	Mog. Pref. or Mog. Screw
			900	28–32	T-20	C-13	Mog. Pref. or Mog. Screw
			600	28–32	T-20	C-13	Mog. Pref. or Mog. Screw
Holmes	......	Holmes Projector Corp.	1000	115	T-20	C-13A	Mog. Screw
			900	28–32	T-20	C-13	Mog. Screw
Super DeVry	SE	DeVry Corp.	1000	115	T-20	C-13A	Mog. Screw
			900	28–32	T-20	C-13	Mog. Screw
			600	28–32	T-20	C-13	Mog. Screw
PORTABLE MOTION PICTURE PROJECTORS (35-mm. Film)							
Acme	12	International Projector Corp.	500	115	T-20	C-13	Med. Pref. or Med. Screw
			300	28–32	T-16	C-13	Med. Pref. or Med. Screw
DeVry	E	DeVry Corp.	500	115	T-20	C-13	Med. Pref. or Med. Screw
DeVry	EU	DeVry Corp.	500	115	T-20	C-13	Med. Pref. or Med. Screw
			300	28–32	T-16	C-13	Med. Pref. or Med. Screw
Holmes	......	Holmes Projector Corp.	500	115	T-20	C-13	Med. Screw
PORTABLE MOTION PICTURE PROJECTORS (16-mm. Film)							
Automatic Advertiser	......	Automatic Advertiser, Inc.	200	115	T-10	C-13	Med. Pref.
Capitol (Continuous)	C Type 3	Capitol Machine Co., Inc.	500	115	T-20	C-13	Med. Pref.
Capitol (Continuous)	A Type 11	Capitol Machine Co., Inc.	500	115	T-20	C-13	Med. Pref.
			200	115	T-10	CC-13	Med. Pref.
DeVry	G	DeVry Corp.	200	115	T-10	CC-13	Med. Pref.
Filmo	......	Bell & Howell Co.	200	50	T-10	C-13	Special
Kodascope	A	Eastman Kodak Co.	200	50	T-10	C-13	Med. Screw
Kodascope	B	Eastman Kodak Co.	200	50	T-10	C-13	Med. Pref.
Kodascope	C	Eastman Kodak Co.	100	115	T-8½	CC-13	Med. Pref.
Q. R. S.	......	Q. R. S. Music Roll Co.	200	115	T-10	CC-13	No. 1857 Special Pref.‡
Victor	3	Victor Animatograph Co.	200	50	T-10	C-13	Med. Pref.
			200	115	T-10	CC-13	Med. Pref.
			165	28–32	T-10	C-13	Med. Pref.

* In the design of newer models of non-theatrical projectors the tendency is toward adoption of the prefocused socket.
‡ Special base—not recommended to designers of new equipments.

PICTURE PROJECTION WITH MAZDA LAMPS

PICTURE PROJECTORS AND THE LAMPS THEY USE

Projector	Model	Manufacturer	MAZDA LAMP USED				
			Watts	Volts	Bulb	Filament	Base*
STEREOPTICON—GLASS SLIDE AND OPAQUE							
Balopticon	B, BBM, HRM, HRMD, LRM, KRMS	Bausch & Lomb Optical Co.	500	115	T-20	C-13	Med. Sc. Skirted
Balopticon	D, CL, CRM, O	Bausch & Lomb Optical Co.	1000	115	G-40	C-13A	Mog. Screw
Beseler	A, B, C, D, DD, OA1, OA2	Chas. Beseler Co.	500	115	T-20	C-13	Med. Screw
Beseler	C	Chas Beseler Co.	500	115	T-20	C-13	Med. Pref.
Beseler	E	Chas Beseler Co.	600‡	115	T-20	C-13	Mog. Screw
Beseler	F, FE	Chas. Beseler Co.	900	28–32	T-20	C-13	Mog. Screw
			1000	115	T-20	C-13A	Mog. Screw
Beseler	OA3	Chas. Beseler Co.	1000	115	G-40	C-13A	Mog. Screw
Brenkert	......	Brenkert Light Projection Co.	500	115	T-20	C-13	Med. Screw
Brenkert	F2, F6	Brenkert Light Projection Co.	1000	115	T-20	C-13A	Mog. Screw
Delineascope	C, D, E, F, H, N, S, SA	Spencer Lens Co.	500	115	T-20	C-13	Mog. Screw
Delineascope	J	Spencer Lens Co.	1000	115	T-20	C-13A	Mog. Screw
Delineascope	P, R	Spencer Lens Co.	1000	115	G-40	C-13A	Mog. Screw
DeVry	T, M	DeVry Corp.	400‡	115	T-20†	C-13	Med. Screw
Victor	2, 3	Victor Animatograph Co.	500	115	T-20	C-13	Med. Pref. or Med. Screw
STEREOPTICON—FILM SLIDE (35 mm. Film)							
Balopticon	4102-3	Bausch & Lomb Optical Co.	100	115	T-8½	C-13	Med. Pref.
Balopticon	4090	Bausch & Lomb Optical Co.	200	115	T-10	C-13	Med. Pref.
Balopticon	ABMF	Bausch & Lomb Optical Co.	400‡	115	T-20	C-13	Med. Screw
Brayco	......	Agfa-Ansco Corp.	21 c.p.	12–16	S-11	......	D.C.Cand.Bay. (MAZDA No. 1142)
Delineascope	I, L, M	Spencer Lens Co.	200	115	T-10	C-13	Med. Pref.
Delineascope	T	Spencer Lens Co.	165‡	115	T-10	C-13	Med. Pref.
Jam Handy Explainer	......	Newspaper Film Corp.	200	115	T-10	C-13	Med. Screw
Jam Handy Pocket Explainer	......	Newspaper Film Corp.	50	115	T-8	CC-13	S. C. Bay. Cand.
Memoscope	......	Agfa-Ansco Corp.	100	115	T-8½	C-13	Med. Pref.
S.V.E.	......	Society for Visual Education	200	115	T-10	C-13	Med. Pref.
S.V.E. Pocket Explainer	......	Society for Visual Education	50	115	T-8	CC-13	S. C. Bay. Cand.
Visual Demonstrator	......	Visual Demonstration System, Inc.	200	115	T-10	CC-13	Med. Pref.
Wyko	......	Wyko Projector Corp.	250‡	115	T-14	C-13	Med. Screw

Light center length of Medium Prefocused base lamps.....$2\frac{3}{16}$ inches measured from top of fins to filament center
Light center length of Medium Screw base lamps approx...3 inches measured from bottom contact to filament center
Light center length of Mogul Prefocused base lamps.......$3\frac{7}{16}$ inches measured from top of fins to filament center
Light center length of Mogul Screw base lamps approx....4¾ inches measured from bottom contact to filament center

* In the design of newer models the tendency is toward adoption of the prefocused socket.

† Special bulb—5¼ inches over-all length.

‡ Special lamp not recommended to designers of new equipments, substitute a standard lamp (see page 36) in existing equipments wherever possible.

watt, 50-volt lamp gives the best average performance in 16-mm. optical systems, and in the 115-volt range, the 200-watt rating is also the maximum effective limit.

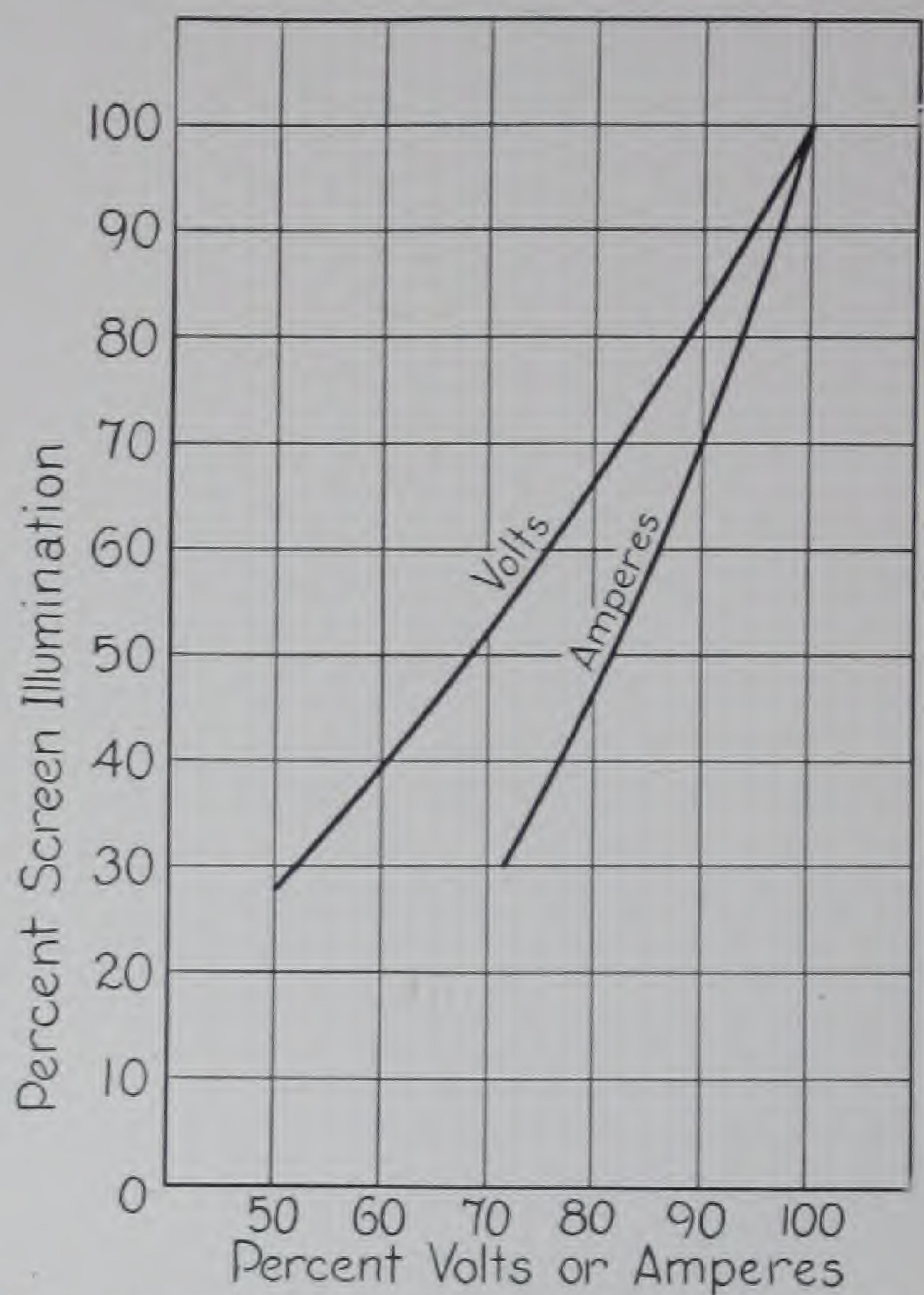

Fig. 39—These curves show the rapidity with which the screen illumination falls off with a reduction in the voltage applied to the lamp, and with the current consumed by the lamp.

Experience indicates that in general the 900-watt, 30-ampere lamp with proper equipment gives excellent screen illumination for theaters and auditoriums having a seating capacity on the main floor up to 1,000 where the distance from the projector to the screen does not exceed 100 feet and where the picture width is not over 16 feet. It is assumed in the above statement that the No. 2 size objective lenses are in all cases employed for focal lengths of 4½ inches and above, and that the screen surface is maintained in good condition.

MAZDA projection lamps are of gas-filled construction and are designed for operation base-down, or within 25 degrees of the vertical; at a greater angle their performance may be somewhat impaired. The tubular bulb permits the light source to be placed close to the condenser, which may thus be designed for short focal length and high efficiency, and at the same time results in excellent maintenance of candlepower during life. The 900-watt lamp is made for operation at constant current rather than at constant voltage. The regulating equipment must be capable of accurate current adjustment, for both lamp life and light output are radically affected by operation at other than rated current. At 31 amperes, the life of the 30-ampere lamp is reduced by about one-half; at 29 amperes the screen illumination is reduced materially. The importance of operating all projection lamps at their respective current or voltage rating cannot be emphasized too strongly.

PROJECTION EQUIPMENT

In addition to the optical elements previously discussed a motion picture or stereopticon projector requires a well-ventilated lamp house, some means of accurately locating the lamp filament on the optical axis —either a preset or an adjustable lamp holder—and, except for accurately-made portable equipments, an adjustable mirror holder. Standard motion picture theater projectors and those portable equipments which also employ low voltage lamps require in addition a regulating device and ammeter.

Ventilation

To insure good lamp performance, it is necessary to provide ample ventilation of the lamp house. Radiation alone should not be depended upon, but provision should be made for circulation of air past the lamp base and bulb. The temperature may become high enough to soften the bulb or to cause deterioration of the lamp holder, particularly the insulation, if air inlet and outlet openings of ample size are not provided. Special precaution must be taken in the case of portable equipments where light weight and compactness are important features.

The use of a small fan connected to the motor driving the film mechanism is recommended to force a large volume of air through the lamp housing. This arrangement makes possible a smaller housing than when natural ventilation is used. In the latter case, the inlet openings at the bottom of the housing should have a total area of at least 0.015 square inches per watt, and outlet openings at the top equal to or larger than this figure.

Adjustment of Light Source

So sensitive is the optical system of a motion picture projector to the position of the light source that a small displacement of the latter causes a marked loss in the light reaching the screen, and in the uniformity of the illumination.

If a light source in a 35-mm. motion picture projector is displaced laterally only as much as one-eighth of an inch from its correct position on the optical axis, the screen illumination is reduced 25 per cent. An equal deviation causes a somewhat greater loss in 16-mm. optical systems. Portable projectors should be provided with prefocused lamps and the 900-watt, 30-ampere equipments with a presetting device.

The lamp holder or presetting device should provide for locating the filament vertically, laterally and longitudinally on the optical axis

Fig. 40—Lateral adjustment of lamp in setter.

Fig. 41—Alignment of lamp filament for distance from condensing lens.

and also for placing it so that the plane of the coils may be set facing the condenser. Adjustment of the light source should first be made without the reflector. The lamp is turned so that the plane of the filament coils is perpendicular to the optical axis and it is then moved laterally and vertically until the center of the filament area is on the optical axis. In order that a new lamp inserted at any time thereafter may be exactly placed without delay for adjustment after a burnout, the plan of using removable sockets sliding into guides is to be recommended for standard theater motion picture projectors. To realize this advantage it is necessary that the lamps be first aligned in individual sockets in a gauge or presetter, such as the device shown above, which provides the four essential adjustments:

1—Height of the filament, by screwing the center base contact up or down until the lower ends of the coils are in line with the two sighting holes in the setter (Fig. 40);

2—Lateral adjustment, by moving the lamp against a spring by means of a thumb screw, until the coils are centered in line with two pointed sights (Fig. 40);

3—Adjustment for distance from the condenser, by means of another thumb screw by which the filament is set in line with two V sights (Fig. 41) at right angles with the plane of the pointed sights;

4—Plane of the filament, by alignment parallel with the V sights (Fig. 41).

The adjustments in the device illustrated are made with the lamp base loose in a special split ring socket which is not threaded; the lamp is fixed in position in the socket by tightening two screws which draw a collar over the split ring, rigidly holding the lamp in its adjusted position in the socket. By opening the hinged top of the setter, the lamp and socket can be removed as a unit with the assurance that when they are placed in the guides provided in the housing, the lamp filament will be correctly aligned with respect to the condenser and optical axis.

If no presetting arrangement is provided in an equipment the best procedure is to place the light source by measurement at the specified distance behind the condenser. Then with the lamp lighted, the spot produced is centered on the aperture plate by moving the lamp vertically and horizontally; this gives an approximate setting of the light source. It can then be made more accurate by intercepting the beam through the open aperture on the rotary shutter or on a black card held where the filament image is most sharp and adjusting the lamp until this image is centered in the illuminated spot, as shown in Fig. 42. The attempt is sometimes made to adjust the lamp by centering the image formed on the fire shutter through a small hole in the dowser, but the desired result is usually not obtained because the hole in the dowser is seldom exactly in the optical axis.

Accurate alignment of the optical system and adjustment of the lamp filament are just as important factors with portable projectors as with standard theater equipments. Some equipments provide lateral, vertical, longitudinal and rotational movements for the lamp socket which enable the user to properly align the lamp filament. However, some skill is required to set the lamp so as to give maximum illumination, and the task is especially difficult if the lamp housing is hot. In many modern equipments this is automatically accomplished by the use of lamps with prefocused bases. The lamp filament is prefocused with a special base at the factory so that its position always bears the same

Fig. 42—Filament image projected on rotary shutter for observation in adjusting lamps.

Fig. 43—Typical medium and mogul prefocus sockets as used in projection equipment.

relation to fins on the base. The socket designed to accommodate this base—the prefocus socket—is rigidly attached to the projector in the correct position by the equipment manufacturer. No further adjustment is necessary. The prefocusing base and socket are available in two sizes, corresponding to the medium and mogul screw bases and sockets. (Fig. 43).

Adjustment of Mirrored Reflector

Proper adjustment of the reflector markedly increases the amount and uniformity of screen illumination. With the aspheric and prismatic condensers, the most satisfactory practical method of setting the mirror in standard theater equipment is to close the dowser and observe the image of the coils formed on the fire shutter through a small hole in the center of the dowser. For the mirror adjustment it is not important that this hole be exactly in the optical axis. With the lamp operated at normal current, the mirror may be moved into a position where an image of the reflected coils will be observed. The mirror is moved back and forth until this image is of the *same size* as the image of the filaments. It is then slightly tilted or moved laterally and vertically until the image of the reflected coils

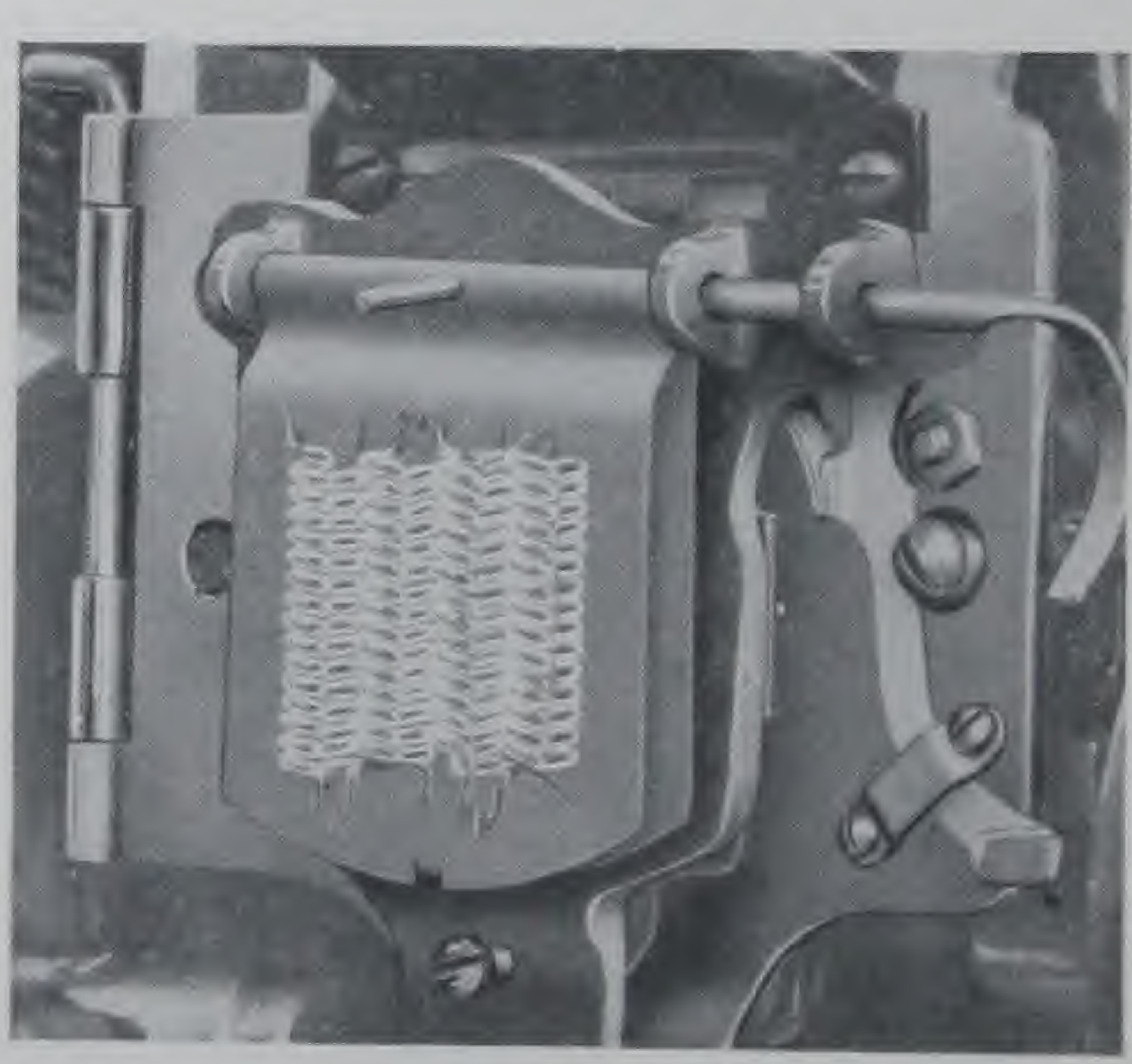

Fig. 44—Pinhole images of lamp filament and reflected coils on fire shutter for observation in setting mirrored reflector.

appears in the spaces between the coils of the filament image, as shown in Fig. 44. On some of the theater projection machines the lamp house may be moved to one side. In this case, the image of the coils coming through the dowser hole may be shown greatly enlarged against the wall of the projection room, making it easier to observe the position of the reflected coils. It is very important that the two images be adjusted to the same size. It will be noted that the image of the reflected coils is inverted and reversed; the right segment of the direct image shows as the left segment of the reflected coils.

The mechanism of a motion picture projector always causes some vibration, hence all clamping screws must be kept tightened to preserve the alignment of the optical elements. The adjustments should be examined from time to time, and in case a lamp is replaced during the progress of the performance, the adjustment should be checked at the first opportunity.

Because of the compactness of the portable equipments, it is seldom practicable to use the method explained above in focusing the mirrored reflector. In the case of the newer equipments fitted with prefocus sockets and using prefocused lamps, it is desirable that the mirrored reflector be rigidly fixed in position by the manufacturer. In the case of older equipments the mirror is ordinarily adjustable, and to obtain best illumination results, care should be taken in setting it. Focusing can be accomplished by holding a black card in back of the lens where an image of the filament and mirror are usually formed; in event the optical system is entirely enclosed, the lens should be removed and the card held at the image position—the mirror can then be adjusted until its image of the filament is meshed between the first or lens image of the filament coils.

Current Regulation

Standard theater equipments should have a current regulator designed so that for any variation that may be expected in the line voltage, the lamp amperage may be held constant. The regulating device should be so arranged that in starting the 900-watt, 28-32 volt lamp, about half normal voltage is momentarily impressed, causing the heavy filament to heat up gradually. An accurate ammeter should be placed in series with the lamp, and the 30-ampere point on the meter scale distinctly marked so that a deviation from normal current will at once be apparent. The ammeter should be checked at least every six months.

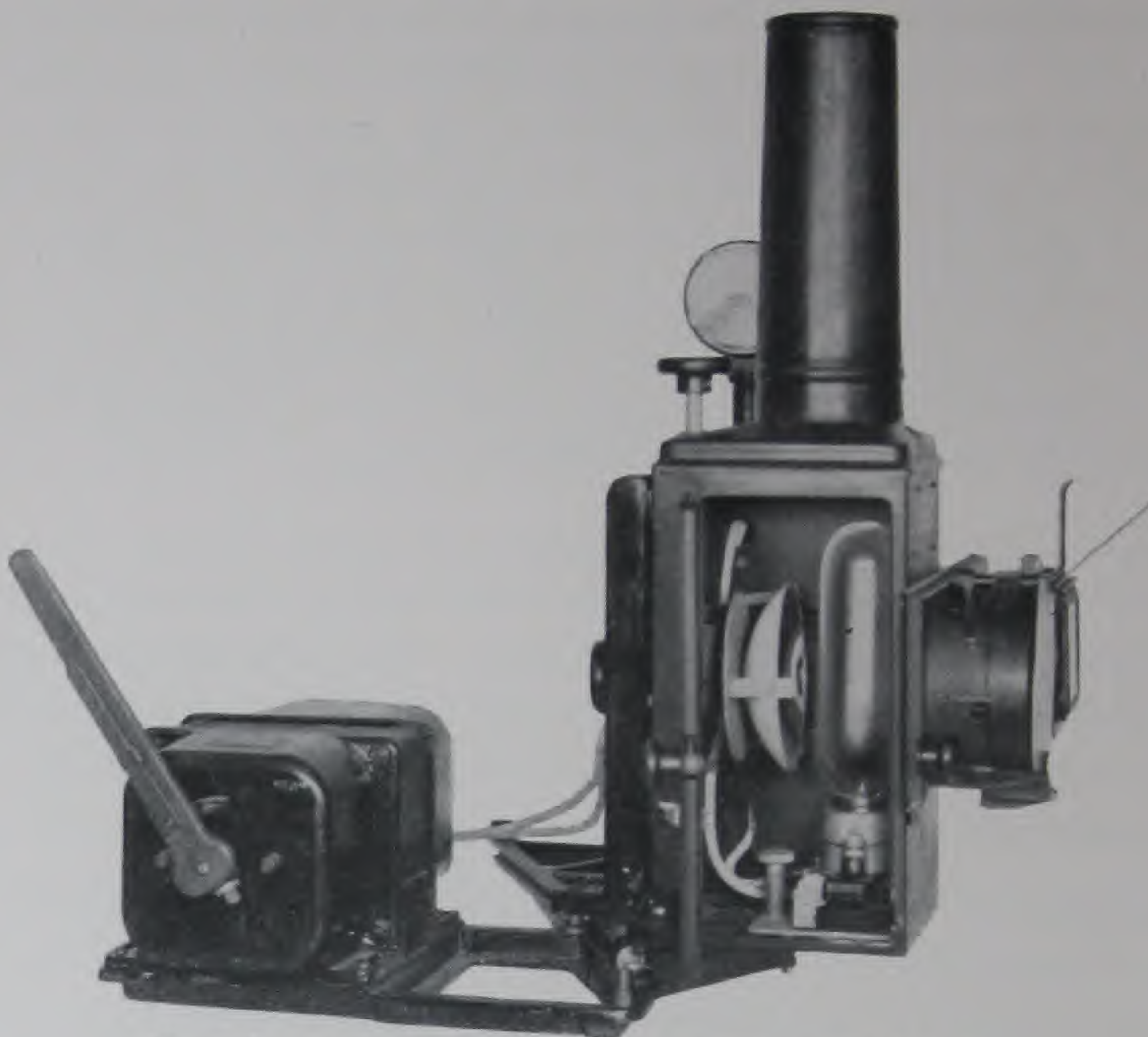

Fig. 45—Complete equipment for adapting MAZDA lamps to standard projectors.

On alternating current a transformer-regulator should be used with the 900-watt lamp to reduce the circuit voltage to that of the lamp. Well designed units of the type shown in Fig. 45 have an efficiency of about 90 per cent, making the total wattage required for a 30-ampere lamp about 1,000 watts.

With direct current, either a motor-generator set, a converter, or a series rheostat can be employed on commercial lighting and power circuits. While the initial installation of a series rheostat is much less expensive, this is more than offset by its higher operating cost. In the case of the 900-watt lamp operated on a 115-volt circuit, 2,550 watts are lost in the rheostat—almost three times the power consumed by the lamp.

A motor generator set together with the alternating current regulator entails a loss of less than 500 watts with the 900-watt lamp, as compared with 2,550 for rheostat operation.

A rotary converter, for changing direct current to alternating current, combines the two windings of the motor-generator set on one

rotor; the cost is less, and efficiency is higher than for the motor-generator set. The energy loss in both the converter and an alternating current regulator is only about 350 watts.

Most of the portable projectors employ lamps of standard circuit voltage—110, 115 and 120 volts. These require no regulating equipment, but lamps of the voltage rating corresponding to that of the circuit on which they are employed should of course be used. In the case of the small portable units employing the 200-watt, 50-volt lamp, the use of a series resistance is more practical than a transformer since this is universally applicable to either alternating or direct current circuits. For the best results with the 50-volt lamp, the series resistance should be variable, and an ammeter should be provided to enable proper adjustment to the circuit voltages.

APPENDIX

The following tables show the relation of the three variables in projection, i.e., focal length of objective lens—projection distance, and picture size. When the values of any two are known the third may be readily found in the tabulation.

These tables are particularly useful in connection with setting up portable equipment where various limitations on throw or picture size are encountered.

APPENDIX

Table III

Picture Dimensions for Objective Lenses of Various Focal Lengths and Distances from Screen, Lantern Slide with 2¼″ x 3″ Matte Opening

Equivalent Focal Length, In.		THROW IN FEET												
		15	20	25	30	35	40	45	50	60	70	80	90	100
6	Width	7′- 3″	9′- 9″	12′- 3″	14′- 9″	17′- 3″	19′- 9″	22′- 3″	24′- 9″					
	Height	5′- 5″	7′- 4″	9′- 2″	11′- 1″	12′-11″	14′-10″	16′- 8″	18′- 7″					
8	Width	5′- 5″	7′- 3″	9′- 2″	11′- 0″	12′-11″	14′- 9″	16′- 8″	18′- 6″	22′- 3″	26′- 0″			
	Height	4′- 1″	5′- 5″	6′- 9″	8′- 3″	9′- 8″	11′- 1″	12′- 6″	13′-11″	16′- 8″	19′- 6″			
10	Width	4′- 3″	5′- 9″	7′- 3″	8′- 9″	10′- 3″	11′- 9″	13′- 3″	14′- 9″	17′- 9″	20′- 9″	23′- 9″		
	Height	3′- 2″	4′- 4″	5′- 5″	6′- 7″	7′- 8″	8′-10″	9′-11″	11′- 1″	13′- 4″	15′- 7″	17′-10″		
12	Width	....	4′- 9″	6′- 0″	7′- 3″	8′- 6″	9′- 9″	11′- 0″	12′- 3″	14′- 9″	17′- 3″	19′- 9″	22′- 3″	24′- 9″
	Height	....	3′- 7″	4′- 6″	5′- 5″	6′- 5″	7′- 4″	8′- 3″	9′- 2″	11′- 1″	12′-11″	14′-10″	16′- 8″	18′- 7″
15	Width	....	3′- 9″	4′- 9″	5′- 9″	6′- 9″	7′- 9″	8′- 9″	9′- 9″	11′- 9″	13′- 9″	15′- 9″	17′- 9″	19′- 9″
	Height	....	2′-10″	3′- 7″	4′- 3″	5′- 1″	5′-10″	6′- 7″	7′- 4″	8′-10″	10′- 4″	11′-10″	13′- 4″	14′-10″
18	Width	....	....	....	4′- 9″	5′- 7″	6′- 5″	7′- 3″	8′- 1″	9′- 9″	11′- 5″	13′- 1″	14′- 9″	16′- 5″
	Height	....	....	....	3′- 7″	4′- 2″	4′-10″	5′- 5″	6′- 1″	7′- 4″	8′- 7″	9′-10″	11′- 1″	12′- 4″
20	Width	....	....	....	4′- 3″	5′- 0″	5′- 9″	6′- 6″	7′- 3″	8′- 9″	10′- 3″	11′- 9″	13′- 3″	14′- 9″
	Height	....	....	....	3′- 2″	3′- 9″	4′- 4″	4′-11″	5′- 5″	6′- 7″	7′- 8″	8′-10″	9′-11″	11′- 1″
22	Width	....	....	....	....	....	5′- 3″	5′-11″	6′- 7″	7′-11″	9′- 4″	10′- 5″	12′- 0″	13′- 5″
	Height	....	....	....	....	....	3′-11″	4′- 5″	4′-11″	5′-11″	7′- 0″	7′-10″	9′- 0″	10′- 1″
24	Width	....	....	....	....	....	4′- 9″	5′- 5″	6′- 0″	7′- 3″	8′- 6″	9′- 7″	11′- 0″	12′- 3″
	Height	....	....	....	....	....	3′- 7″	4′- 1″	4′- 6″	5′- 5″	6′- 5″	7′- 2″	8′- 3″	9′- 2″

Table IV

Picture Dimensions for Objective Lenses of Various Focal Lengths and Distances from Screen—16-mm. Motion Picture Film

Equivalent Focal Length, In.		THROW IN FEET					
		8	10	12	16	20	25
1	Width	3′- 0″	3′- 9″	4′- 6″	6′- 1″	7′- 7″	9′- 6″
	Height	2′- 3″	2′- 9″	3′- 4″	4′- 6″	5′- 7″	7′- 0″
1½	Width	2′- 0″	2′- 6″	3′- 0″	4′- 0″	5′- 1″	6′- 4″
	Height	1′- 6″	1′-10″	2′- 3″	3′- 0″	3′- 9″	4′- 8″
2	Width	1′- 6″	1′-11″	2′- 3″	3′- 0″	3′- 9″	4′- 9″
	Height	1′- 1″	1′- 5″	1′- 8″	2′- 3″	2′- 9″	3′- 6″
2½	Width	1′- 3″	1′- 6″	1′-10″	2′- 5″	3′- 0″	3′- 9″
	Height	0′-11″	1′- 1″	1′- 4″	1′-10″	2′- 3″	2′-10″
3	Width	1′- 0″	1′- 3″	1′- 6″	2′- 0″	2′- 7″	3′- 2″
	Height	0′- 9″	0′-11″	1′- 1″	1′- 6″	1′-10″	2′- 4″
3½	Width	0′-10″	1′- 1″	1′- 4″	1′- 9″	2′- 2″	2′- 8″
	Height	0′- 8″	0′-10″	0′-11″	1′- 3″	1′- 7″	2′- 0″
4	Width	0′- 9″	0′-11″	1′- 2″	1′- 6″	1′-10″	2′- 4″
	Height	0′- 7″	0′- 8″	0′-10″	1′- 1″	1′- 5″	1′- 9″

NOTE

Because of limitations in the size of light source used in these projectors, the brightness of the picture is too low for satisfactory viewing if the throw is much greater than 25 feet.

Table V
Picture Dimensions for Objective Lenses of Various Focal Lengths and Distances from Screen—35-mm. Film

Equivalent Focal Length, In.		THROW IN FEET												
		8	10	12	16	20	25	30	35	40	45	50	55	60
1	Width	7′- 2″	9′- 0″	10′-10″	14′- 5″	18′- 1″	22′- 7″							
	Height	5′- 5″	6′- 9″	8′- 1″	10′-10″	13′- 6″	16′-11″							
1½	Width	4′- 9″	6′- 0″	7′- 2″	9′- 7″	12′- 0″	15′- 0″							
	Height	3′- 7″	4′- 6″	5′- 4″	7′- 2″	9′- 0″	11′- 3″							
2	Width	3′- 7″	4′- 5″	5′- 4″	7′- 2″	9′- 0″	11′- 3″	13′- 6″						
	Height	2′- 8″	3′- 4″	4′- 0″	5′- 4″	6′- 9″	8′- 5″	10′- 2″						
2½	Width	2′-10″	3′- 7″	4′- 3″	5′- 9″	7′- 2″	9′- 0″	10′-11″	12′- 6″					
	Height	2′- 1″	2′- 8″	3′- 2″	4′- 3″	5′- 4″	6′- 9″	8′- 2″	9′- 4″					
3	Width	2′- 4″	2′-11″	3′- 7″	4′- 9″	6′- 0″	7′- 6″	9′- 1″	10′- 7″	12′- 0″				
	Height	1′- 9″	2′- 2″	2′- 8″	3′- 7″	4′- 6″	5′- 7″	6′-10″	7′-11″	9′- 0″				
3½	Width	2′- 1″	2′- 6″	3′- 1″	4′- 1″	5′- 1″	6′- 5″	7′- 8″	9′- 0″	10′- 3″	11′- 7″	12′-10″	14′- 2″	15′- 5″
	Height	1′- 7″	1′-11″	2′- 3″	3′- 1″	3′-10″	4′- 9″	5′- 9″	6′- 9″	7′- 9″	8′- 8″	9′- 8″	10′- 7″	11′- 7″
3¾	Width	1′-10″	2′- 4″	2′-10″	3′- 9″	4′- 9″	6′- 0″	7′- 2″	8′- 5″	9′- 7″	10′-10″	12′- 0″	13′- 3″	14′- 5″
	Height	1′- 5″	1′- 9″	2′- 1″	2′-10″	3′- 7″	4′- 6″	5′- 5″	6′- 3″	7′- 2″	8′- 1″	9′- 0″	9′-11″	10′-10″
4	Width	1′- 9″	2′- 2″	2′- 8″	3′- 7″	4′- 5″	5′- 7″	6′- 9″	7′-10″	9′- 0″	10′- 1″	11′- 3″	12′- 5″	13′- 6″
	Height	1′- 4″	1′- 8″	2′- 0″	2′- 8″	3′- 4″	4′- 2″	5′- 0″	5′-11″	6′- 9″	7′- 7″	8′- 5″	9′- 4″	10′- 2″
4¼	Width	....	....	....	3′- 5″	4′- 2″	5′- 4″	6′- 4″	7′- 5″	8′- 5″	9′- 6″	10′- 7″	11′- 8″	12′- 9″
	Height	....	....	....	2′- 6″	3′- 2″	4′- 0″	4′- 9″	5′- 6″	6′- 4″	7′- 2″	7′-11″	8′- 9″	9′- 6″
4½	Width	....	....	....	....	3′-11″	5′- 0″	6′- 0″	7′- 0″	8′- 0″	9′- 0″	10′- 0″	11′- 0″	12′- 0″
	Height	....	....	....	....	3′- 0″	3′- 9″	4′- 6″	5′- 3″	6′- 0″	6′- 9″	7′- 6″	8′- 3″	9′- 0″
4¾	Width	....	....	....	....	....	4′- 9″	5′- 8″	6′- 7″	7′- 7″	8′- 6″	9′- 6″	10′- 5″	11′- 5″
	Height	....	....	....	....	....	3′- 7″	4′- 3″	5′- 0″	5′- 8″	6′- 5″	7′- 1″	7′-10″	8′- 6″
5	Width	....	....	....	....	....	....	5′- 4″	6′- 3″	7′- 2″	8′- 1″	9′- 0″	9′-11″	10′-10″
	Height	....	....	....	....	....	....	4′- 0″	4′- 8″	5′- 5″	6′- 1″	6′- 9″	7′- 5″	8′- 1″
5¼	Width	....	....	....	....	....	....	5′- 1″	6′- 0″	6′-10″	7′- 8″	8′- 7″	9′- 5″	10′- 3″
	Height	....	....	....	....	....	....	3-′10″	4′- 6″	5′- 2″	5′- 9″	6′- 5″	7′- 1″	7′- 9″
5½	Width	....	....	....	....	....	....	4′-10″	5′- 8″	6′- 6″	7′- 4″	8′- 2″	9′- 0″	9′-10″
	Height	....	....	....	....	....	....	3′- 8″	4′- 3″	4′-11″	5′- 6″	6′- 2″	6′- 9″	7′- 4″
5¾	Width	....	....	....	....	....	....	....	5′- 5″	6′- 3″	7′- 0″	7′-10″	8′- 7″	9′- 4″
	Height	....	....	....	....	....	....	....	4′- 1″	4′- 8″	5′- 3″	5′-10″	6′- 5″	7′- 0″
6	Width	....	....	....	....	....	....	....	5′- 3″	6′- 0″	6′- 9″	7′- 6″	8′- 3″	9′- 0″
	Height	....	....	....	....	....	....	....	3′-11″	4′- 6″	5′- 0″	5′- 7″	6′- 2″	6′- 9″
6¼	Width	....	....	....	....	....	....	....	5′- 0″	5′- 9″	6′- 6″	7′- 2″	7′-11″	8′- 8″
	Height	....	....	....	....	....	....	....	3′- 9″	4′- 4″	4′-10″	5′- 5″	5′-11″	6′- 6″
6½	Width	....	....	....	....	....	....	....	....	5′- 6″	6′- 3″	6′-11″	7′- 7″	8′- 3″
	Height	....	....	....	....	....	....	....	....	4′- 2″	4′- 8″	5′- 2″	5′- 8″	6′- 3″
6¾	Width	....	....	....	....	....	....	....	....	....	6′- 0″	6′- 8″	7′- 4″	8′- 0″
	Height	....	....	....	....	....	....	....	....	....	4′- 6″	5′- 0″	5′- 6″	6′- 0″
7	Width	....	....	....	....	....	....	....	....	....	5′- 9″	6′- 5″	7′- 1″	7′- 8″
	Height	....	....	....	....	....	....	....	....	....	4′- 4″	4′-10″	5′- 3″	5′- 9″
7¼	Width	....	....	....	....	....	....	....	....	....	5′- 7″	6′- 2″	6′-10″	7′- 5″
	Height	....	....	....	....	....	....	....	....	....	4′- 2″	4′- 8″	5′- 1″	5′- 7″
7½	Width	....	....	....	....	....	....	....	....	....	....	6′- 0″	6′- 7″	7′- 2″
	Height	....	....	....	....	....	....	....	....	....	....	4′- 6″	4′-11″	5′- 5″
7¾	Width	....	....	....	....	....	....	....	....	....	....	5′- 9″	6′- 4″	6′-11″
	Height	....	....	....	....	....	....	....	....	....	....	4′- 4″	4′- 9″	5′- 3″

Table V—(Continued)
Picture Dimensions for Objective Lenses of Various Focal Lengths and Distances from Screen—35-mm. Film

Equivalent Focal Length, In.		THROW IN FEET												
		65	70	75	80	85	90	95	100	105	110	115	120	125
3½	Width	16′- 9″	18′- 1″	19′- 4″	20′- 8″									
	Height	12′- 7″	13′- 7″	14′- 6″	15′- 6″									
3¾	Width	15′- 8″	16′-10″	18′- 1″	19′- 3″	20′- 5″	21′- 8″							
	Height	11′- 9″	12′- 8″	13′- 7″	14′- 6″	15′- 4″	16′- 3″							
4	Width	14′- 8″	15′- 9″	16′-11″	18′- 1″	19′- 2″	20′- 4″	21′- 5″	22′- 7″					
	Height	11′- 0″	11′-10″	12′- 8″	13′- 7″	14′- 5″	15′- 3″	16′- 1″	16′-11″					
4¼	Width	13′- 9″	14′-10″	15′-11″	17′- 0″	18′- 1″	19′- 1″	20′- 2″	21′- 3″	22′- 4″	23′- 5″			
	Height	10′- 4″	11′- 2″	12′- 0″	12′- 9″	13′- 7″	14′- 4″	15′- 2″	15′-11″	16′- 9″	17′- 7″			
4½	Width	13′- 0″	14′- 0″	15′- 0″	16′- 0″	17′- 0″	18′- 1″	19′- 0″	20′- 1″	21′- 1″	22′- 1″	23′- 1″	24′- 1″	
	Height	9′- 9″	10′- 6″	11′- 3″	12′- 1″	12′- 9″	13′- 6″	14′- 3″	15′- 1″	15′-10″	16′- 7″	17′- 4″	18′- 1″	
4¾	Width	12′- 4″	13′- 4″	14′- 3″	15′- 2″	16′- 2″	17′- 1″	18′- 1″	19′- 0″	20′- 0″	20′-11″	21′-10″	22′-10″	23′- 9″
	Height	9′- 3″	10′- 0″	10′- 8″	11′- 5″	12′- 1″	12′-10″	13′- 7″	14′- 3″	15′- 0″	15′- 8″	16′- 5″	17′- 1″	17′-10″
5	Width	11′- 9″	12′- 7″	13′- 6″	14′- 5″	15′- 4″	16′- 3″	17′- 1″	18′- 1″	19′- 0″	19′-11″	20′- 9″	21′- 8″	22′- 7″
	Height	8′- 9″	9′- 6″	10′- 2″	10′-10″	11′- 6″	12′- 2″	12′-10″	13′- 7″	14′- 3″	14′-10″	15′- 7″	16′- 3″	16′-11″
5¼	Width	11′- 2″	12′- 0″	12′-11″	13′- 9″	14′- 7″	15′- 5″	16′- 4″	17′- 2″	18′- 1″	18′-11″	19′- 9″	20′- 8″	21′- 6″
	Height	8′- 4″	9′- 0″	9′- 8″	10′- 4″	11′- 0″	11′- 7″	12′- 3″	12′-11″	13′- 7″	14′- 2″	14′-10″	15′- 6″	16′- 1″
5½	Width	10′- 8″	11′- 6″	12′- 4″	13′- 1″	13′-11″	14′- 9″	15′- 7″	16′- 5″	17′- 3″	18′- 0″	18′-11″	19′- 8″	20′- 6″
	Height	8′- 0″	8′- 7″	9′- 3″	9′-10″	10′- 6″	11′- 1″	11′- 8″	12′- 4″	12′-11″	13′- 7″	14′- 2″	14′- 9″	15′- 5″
5¾	Width	10′- 2″	11′- 0″	11′- 9″	12′- 7″	13′- 4″	14′- 1″	14′-11″	15′- 8″	16′- 6″	17′- 3″	18′- 1″	18′-10″	19′- 7″
	Height	7′- 8″	8′- 3″	8′-10″	9′- 5″	10′- 0″	10′- 7″	11′- 2″	11′- 9″	12′- 4″	12′-11″	13′- 7″	14′- 2″	14′- 9″
6	Width	9′- 9″	10′- 6″	11′- 3″	12′- 0″	12′- 9″	13′- 6″	14′- 3″	15′- 9″	15′-10″	16′- 6″	17′- 4″	18′- 1″	18′-10″
	Height	7′- 4″	7′-11″	8′- 5″	9′- 0″	9′- 7″	10′- 2″	10′- 9″	11′- 3″	11′-10″	12′- 5″	13′- 0″	13′- 7″	14′- 1″
6¼	Width	9′- 4″	10′- 1″	10′-10″	11′- 6″	12′- 3″	13′- 0″	13′- 8″	14′- 5″	15′- 2″	15′-11″	16′- 7″	17′- 4″	18′- 1″
	Height	7′- 0″	7′- 7″	8′- 1″	8′- 8″	9′- 2″	9′- 9″	10′- 3″	10′-10″	11′- 5″	11′-11″	12′- 6″	13′- 0″	13′- 7″
6½	Width	9′- 0″	9′- 8″	10′- 5″	11′- 1″	11′- 9″	12′- 6″	13′- 2″	13′-11″	14′- 7″	15′- 3″	16′- 0″	16′- 8″	17′- 4″
	Height	6′- 9″	7′- 3″	7′-10″	8′- 4″	8′-10″	9′- 4″	9′-11″	10′- 5″	10′-11″	11′- 5″	12′- 0″	12′- 6″	13′- 0″
6¾	Width	8′- 8″	9′- 4″	10′- 0″	10′- 8″	11′- 4″	12′- 0″	12′- 8″	13′- 4″	14′- 0″	14′- 9″	15′- 5″	16′- 0″	16′- 8″
	Height	6′- 6″	7′- 0″	7′- 6″	8′- 0″	8′- 6″	9′- 0″	9′- 6″	10′- 0″	10′- 6″	11′- 1″	11′- 6″	12′- 0″	12′- 6″
7	Width	8′- 4″	9′- 0″	9′- 8″	10′- 3″	10′-11″	11′- 7″	12′- 3″	12′-11″	13′- 6″	14′- 2″	14′-10″	15′- 6″	16′- 1″
	Height	6′- 3″	6′- 9″	7′- 3″	7′- 9″	8′- 2″	8′- 8″	9′- 2″	9′- 8″	10′- 2″	10′- 7″	11′- 1″	11′- 7″	12′- 1″
7¼	Width	8′- 1″	8′- 8″	9′- 4″	9′-11″	10′- 7″	11′- 2″	11′-10″	12′- 5″	13′- 1″	13′- 8″	14′- 4″	14′-11″	15′- 6″
	Height	6′- 0″	6′- 6″	7′- 0″	7′- 5″	7′-11″	8′- 5″	8′-11″	9′- 4″	9′- 9″	10′- 3″	10′- 9″	11′- 2″	11′- 8″
7½	Width	7′- 9″	8′- 5″	9′- 0″	9′- 7″	10′- 3″	10′-10″	11′- 5″	12′- 0″	12′- 7″	13′- 3″	13′-10″	14′- 5″	15′- 0″
	Height	5′-10″	6′- 3″	6′- 9″	7′- 2″	7′- 8″	8′- 1″	8′- 7″	9′- 0″	9′- 5″	9′-11″	10′- 4″	10′-10″	11′- 3″
7¾	Width	7′- 6″	8′- 1″	8′- 9″	9′- 3″	9′-10″	10′- 5″	11′- 0″	11′- 8″	12′- 2″	12′-10″	13′- 5″	14′- 0″	14′- 6″
	Height	5′- 8″	6′- 1″	6′- 6″	7′- 0″	7′- 5″	7′-10″	8′- 3″	8′- 9″	9′- 2″	9′- 7″	10′- 0″	10′- 6″	10′-11″
8	Width	7′- 3″	7′-10″	8′- 5″	9′- 0″	9′- 7″	10′- 1″	10′- 8″	11′- 3″	11′-10″	12′- 5″	12′-11″	13′- 6″	14′- 1″
	Height	5′- 6″	5′-11″	6′- 4″	6′- 9″	7′- 2″	7′- 7″	8′- 0″	8′- 5″	8′-10″	9′- 4″	9′- 9″	10′- 2″	10′- 7″
8¼	Width	7′- 1″	7′- 7″	8′- 2″	8′- 9″	9′- 3″	9′-10″	10′- 4″	10′-11″	11′- 6″	12′- 0″	12′- 7″	13′- 1″	13′- 8″
	Height	5′- 4″	5′- 9″	6′- 1″	6′- 6″	6′-11″	7′- 4″	7′- 9″	8′- 2″	8′- 7″	9′- 0″	9′- 5″	9′-10″	10′- 3″
8½	Width	6′-10″	7′- 5″	7′-11″	8′- 5″	9′- 0″	9′- 6″	10′- 1″	10′- 7″	11′- 1″	11′- 8″	12′- 2″	12′- 9″	13′- 3″
	Height	5′- 2″	5′- 6″	5′-11″	6′- 4″	6′- 9″	7′- 2″	7′- 6″	7′-11″	8′- 4″	8′- 9″	9′- 2″	9′- 7″	9′-11″
8¾	Width	6′- 8″	7′- 2″	7′- 8″	8′- 3″	8′- 9″	9′- 3″	9′- 9″	10′- 4″	10′-10″	11′- 4″	11′-10″	12′- 4″	12′-11″
	Height	5′- 0″	5′- 5″	5′- 9″	6′- 2″	6′- 7″	6′-11″	7′- 4″	7′- 9″	8′- 1″	8′- 6″	8′-11″	9′- 3″	9′- 8″
9	Width	6′- 6″	7′- 0″	7′- 6″	8′- 0″	8′- 6″	9′- 0″	9′- 6″	10′- 0″	10′- 6″	11′- 0″	11′- 6″	12′- 0″	12′- 6″
	Height	4′-10″	5′- 3″	5′- 7″	6′- 0″	6′- 4″	6′- 9″	7′- 1″	7′- 6″	7′-10″	8′- 3″	8′- 8″	9′- 0″	9′- 5″

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ALLEGHENY DIVISION	PITTSBURGH, PA.
ATLANTIC-FEDERAL DIVISION	NEW YORK, N. Y.
BUCKEYE DIVISION	CLEVELAND, OHIO
CONTINENTAL DIVISION	PHILADELPHIA, PA.
EMPIRE DIVISION	BUFFALO, N. Y.
MICHIGAN DIVISION	DETROIT, MICH.
MIDLAND-FEDERAL DIVISION	CHICAGO, ILL.
MISSISSIPPI VALLEY DIVISION	ST. LOUIS, MO.
NEW ENGLAND DIVISION	BOSTON, MASS.
NORTHERN DIVISION	MINNEAPOLIS, MINN.
PACIFIC DIVISION	OAKLAND, CALIF.
SOUTHERN DIVISION	ATLANTA, GA.
SOUTHWESTERN DIVISION	KANSAS CITY, MO.
SUNBEAM DIVISION	NEW YORK, N. Y.
SUNBEAM DIVISION	CHICAGO, ILL.

AT EACH OF THESE OFFICES A LIGHTING ENGINEER IS AT YOUR SERVICE

ENGINEERING DEPARTMENT

NATIONAL LAMP WORKS
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NELA PARK, CLEVELAND

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